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DELAY ON THE NEW EAST RIVER BRIDGE is reported upon as follows by the engineers: The Pennsylvania Steel Co. has the contract for erecting the steel approaches on both sides, with 15 months from Nov. 7, 1900, to complete erection, at about $1,500,000 for the work. None of this material is yet delivered at the bridge, though at least 1,000 tons of this structure should be in place. The steel company claims that it has been delayed in driving the piles for the Manhattan anchorage foundation. In the Roebling contract the four main cables should all be in place by May 1, 1902. These four cables require the placing of 30,000 wires in all; while only 3,000 wires are now in place. This work is to cost $1,398,000, with $1,000 per day penalty for delay. The steel company's penalty is $300 per day.

THE PROPOSED STRAIT OF CANSO BRIDGE, connecting Cape Breton Island with the mainland, has been surveyed and pronounced feasible. The bridge would connect Port Hastings and Cape Porcupine with a 2,000-ft. span between main piers; the water is 99 ft. deep, and the approaches would be 1,250 and 700 ft. long respectively. The height above water at the eastern end would be about 150 ft.

AN ENGINEER COMMISSION in connection with the proposed Pennsylvania R. R. tunnels under the Hudson and East Rivers has been appointed by that company. The following engineers are to examine and approve of the plans to be adopted before construction is commenced: Col. C. W. Raymond, Engineers Corps, U. S. A.; Charles M. Jacobs, Alfred Noble, Gustav Lindenthal and W. H. Brown, all—except the latter—Members of the American Society of Civil Engineers. This is a most able commission, all of its members being prominent in the profession of engineering and peculiarly fitted to pass judgment upon the serious problems to be discussed.

TEMPORARY ABUTMENT SPANS for bridges are being used extensively on the Iowa lines of the Chicago, Burlington & Quincy R. R., where extensive realinement and reduction of grades is being carried out. A bridge of this kind, designed for a high crossing of a stream whose drainage area does not permit the use of masonry, has three 75-ft. plate-girder spans, and two trestle towers with 30-ft. spans; the towers are at the foot of the bank slopes, and the bank ends of the girder spans rest on temporary pile foundations, beyond which are the temporary abutment spans of 16-ft. I-beams, used to avoid the construction of high parapet or bulkhead walls or new banks. As soon as the banks have settled to their permanent bearings, masonry abutments, with filling, will replace the I-beam spans. This end construction is necessary on account of the excessive shrinkage in high banks built from steam-shovel excavation, the height in this case being 72 ft. from bed of stream to base of rail. The weight of this double-track bridge is 915,000 lbs. The tower pedestals are of concrete, and aggregate 600 cu. yds. of this material. Mr. W. L. Breckenridge is Chief Engineer of the C., B. & Q. R. R. The above particulars are taken from the report presented by the Railway Committee of the Illinois Society of Engineers and Surveyors at the recent annual meeting at Joliet, Ill.

THE MOST SERIOUS RAILWAY ACCIDENT of the week was a collision between a runaway section of a lumber train and some log cars, on the railway line of the Lackawanna Lumber Co., near Cross Forks, Pa., on Jan. 21. Four cars loaded with pulpwood broke loose on a 1½% grade a mile up from the scene of the collision, and running at high speed struck a line of cars that were being loaded. Four men at work on the latter were killed.—— Two men were killed in a freight wreck on the Baltimore & Ohio Ry., near Parkersburg, W. Va., on Jan. 20. The engineer of one of the trains, it is said, was helping his fireman; in this way he failed to see his siding and ran past it, colliding with an opposing train. Engineer and fireman of the former train lost their lives in the collision.——On Jan. 28, the second section of a limited express train on the New York Central & Hudson River Ry. struck a switch engine near Oneida, N. Y. The engineer of the limited was killed.

A CIRCULAR RAILWAY TUNNEL 20 ft. in diameter, and lined with three rings of brick, is an engineering curiosity on the Alabama & Vicksburg Ry. (Queen & Crescent Route). The tunnel is in good ground, and the reason for the adoption of this form of section is a mystery to the present engineers.

REDUCED SPEED FOR TRAINS passing through the Park Avenue tunnel in New York city, as advocated editorially in our last issue, has been adopted by the New York Central management. On Jan. 25 an order was issued by General Manager Franklin requiring enginemen not to exceed a speed of 20 miles per hour in running between the Grand Central station and the northern end of the tunnel. After this order was issued, on Jan. 27, an order has been issued by the State Railroad Commission reducing the speed of trains through the tunnel to a maximum of 18 miles per hour.

A SYSTEM OF WARNING SIGNALS is to be installed in the Bergen tunnel of the Erie R. R. to guard against futher accidents through falls of the roof, such as that which occurred on Dec. 21 last (Eng. News, Dec. 26). A row of incandescent electric lights with red bulbs will be placed inside the tunnel spaced 200 ft. apart. At points 500 ft. apart will be placed switches which will operate to turn current on the whole row of lamps. Should the watchmen who patrol the tunnel find anything wrong, they can turn any of these switches and light the row of warning lamps. The same current will also operate warnings in the signal towers at each end of the tunnel block.

AN EARTHQUAKE SHOOK THE VICINITY OF ST. Louis, Mo., at about 5 o'clock on the morning of Jan. 24, 1902. The disturbance appeared to come in two distinct shocks, but as there are no observing stations in that neighborhood, the direction, amplitude, duration, etc., of the waves could not be determined. The shocks were felt throughout the state of Missouri, and also in eastern Kansas and western Illinois. No lives were lost and no damage to property has been reported.

A COAL-MINE EXPLOSION with great loss of life occurred at the Lost Creek mine, near Oskaloosa, Ia., on the afternoon of Jan. 24. The dead numbered over 20, while many others were injured. Fire followed the explosion, and for a time the entire mine was threatened. The explosion is supposed to have been due to dust in the mine.

THE FIREPROOFING OF ELECTRIC CARS is to be a feature of the 60 new cars for the Mersey Ry. (England), which is the tunnel line under the Mersey River, connecting Liverpool and Birkenhead, which has been operated by steam locomotives since its completion in 1886. Over the motors the cars will have a bottom sheathing of asbestos slate attached to the sills. The compartment for the motorman will also be lined with asbestos, to reduce the danger from fire by the blowing out of fuses, etc. The cars will be 60 ft. long, seating 70 persons each. They will be built by Milnes & Co., of Birkenhead, and equipped by the British Westinghouse Electric & Mfg. Co.

TESTS OF COMPRESSED AIR BRAKES on an electric street car were recently made in St. Louis on the line of railway owned by the city and connecting the water-works pumping stations at Baden and at the Chain of Rocks. As reported by Mr. E. A. Hermann, M. Am. Soc. C. E., Sewer Commissioner of St. Louis, the results of the test were as follows:

Speed of car, miles per hour.	Distance required to stop, ft.	Speed of car, miles per hour.	Distance required to stop, ft.
25	120	10	25
20	100	8	15
15	60		

A CONCRETE BREAKWATER is recommended at Galveston, Tex., as a means of protecting the city from damage by a recurrence of the tidal storm of 1900. The Board of Engineers recommending the work is made up of Gen. H. M. Robert, late Chief of Engineers, U. S. A.; Alfred Noble and H. C. Ripley, and its report starts out with a review of the storms which have inundated the island and city since 1834 down to that of Sept. 8, 1900, which was the most disastrous and the water the highest in the history of the city. The average depth of the water was 12 ft.—6 ft. higher than any of the previous storms. Between 1873 and 1900 82 hurricanes have occurred which originated in the West Indies, 38 of which have entered the Gulf. Of these 38 storms 11 reached the Texas coast, or one for every three and a half years. The Board of Engineers is of the opinion that it is practicable to place Galveston entirely out of the reach of any storm like those from which she suffered previous to 1900 and at the same time make the city safe from any serious damage from water such as was sustained in the one of 1900. To accomplish this object the engineers recommend the building of a solid concrete wall, more than three miles long, connecting with the south jetty near Eighth St.; thence to Sixth St. and Avenue D, and thence across the island and down the beach as far as 39th St., the top of this wall to be 17 ft. above low water or ½ ft. higher than the highest point reached by the water in the storm of 1900. The plan is to raise the grade of the city 8 ft. at Avenue A, 10 ft. at Broadway and 12 ft. at Avenue P. The wall is to be built on piles and protected from undermining by sheet piling and riprap. The top of the embankment for 35 ft. from the sea wall is to be protected by a vitrified brick pavement and 60 ft. further by soil and Bermuda grass. To prevent the water from flooding the city from the west a levee is proposed, extending from 39th St. and Avenue T half to Broadway and 45th St.; thence north as far as Avenue A. The width of this levee is to be 300 ft., with side slopes of 1 ft. in 25 ft.

THE INTERSTATE COMMERCE COMMISSION in its annual report, calls renewed attention to the glaring defects in the statute, which have been pointed out in previous reports. "We certainly believe," says the Commission, "that existing laws should be so amended that railway managers who desire to observe them can do so without risk of sacrificing their property. . . . . The whole law should be revised upon some correct theory and some workable basis."

A NEW RECORD FOR WIRELESS TELEGRAPHY at sea was established by the Cunard Line steamers "Umbria" and "Etruria" on the former boat's last voyage eastward. The two vessels passed on Jan. 22, 1902, and were in communication by their Marconi apparatus from 11.40 a. m. until 3.40 p. m. of that day. The final message was received over 110 nautical miles of distance, which is a record, the best previous distance being 106 nautical miles.

THE PROPOSED TAUNTON-BROCKTON SHIP CANAL, to connect Boston Harbor with Narragansett Bay, is reported upon by the Massachusetts Board of Harbor and Land Commissioners, under the law of 1901. The depth of the canal would be 25 ft., and a uniform width of 130 ft. on the bottom, with side slopes of 1 on 2 in earth, and vertical sides in rock, were adopted. Between the ends of the approach structures the total length of the canal would be 31.79 miles; of this 7.24 miles would be on curves of radii of 5,000 to 10,000 ft.; 2.22 miles on curves of 2,000 to 5,000 ft. radii. There would be 14 locks; six between Boston and the summit, and eight between the summit and the Taunton River; the lifts would vary from 7 to 25 ft.; and on the basis of 20 lockages per day, 35,000,000 cu. ft. of water would be required to operate the locks per day. To supply this water a pumpage system would be most advisable, delivering into a summit level 1,500 ft. long and 130 ft. above tide. The proposed line would cross the railways 11 times; it is proposed to avoid five of these by changing the location of the tracks, and at two of the others drawbridges now exist. The line also crosses 45 highways; in all 20 drawbridges will cross the canal, with a generally clear span of 100 ft. Including right of way, the estimated total cost is $57,618,358.

THE PROPOSED LONDON 999-YEAR LEASE for an American office building, is refused by the London County Council; the Council, however, would treat for a 99-year lease. This decision is in connection with a proposed lease of 750-ft. front on the Strand for the erection of a $10,000,000 office building by an American syndicate headed by Sir Charles Rivers Watson. The site would cover three acres on the Strand and adjoining streets; the building is to be only seven stories high.

A SUCCESSFUL BAG-CONVEYING SYSTEM.

A novel application of conveying and elevating machinery has been made at the works of the Walter Baker Co., Ltd., at Milton, Mass. The installation is the work of the New Jersey Foundry & Machine Co., 26 Cortlandt St., New York, and was built after designs worked out by the general manager of the latter company, Mr. J. H. Cook.

The problem presented at the Baker plant was to transfer bags of cocoa beans, each bag about 18 × 30 × 49 ins. in size, and weighing about 300 lbs., from cars on the railway track at the side of the building to the second floor of a storage warehouse about 60 ft. wide and several hundred feet long. The bags were to be delivered in the loft in such a way as to reduce to a minimum the labor required to stack them into piles.

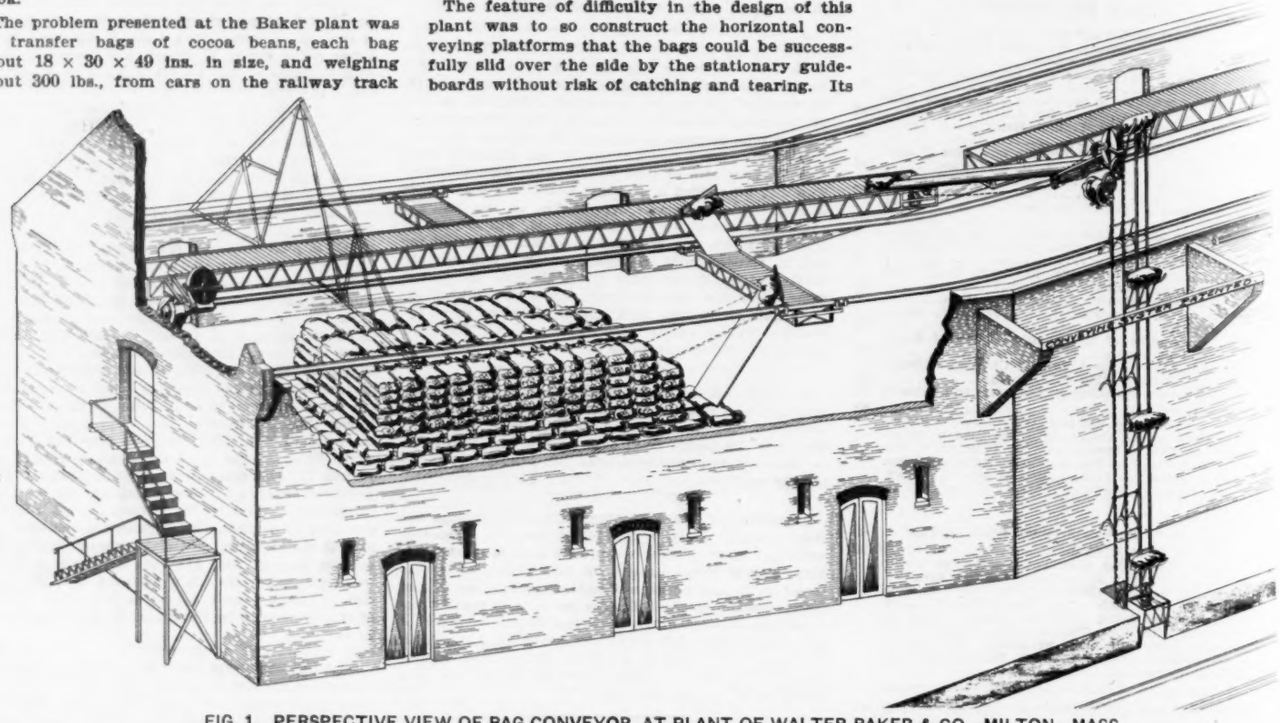


FIG. 1. PERSPECTIVE VIEW OF BAG CONVEYOR AT PLANT OF WALTER BAKER & CO., MILTON, MASS.
Built by the New Jersey Foundry & Machine Works, 26 Cortlandt St., New York.

A perspective view of the completed installation is shown in Fig. 1. A bag elevator is arranged vertically just outside of the building, carrying the bags on sets of projecting arms mounted on an endless chain, which runs between guides. This elevator receives the bags directly from the car and discharges them into an inclined chute extending into the building to the center line, and lying wholly above the bottom chord of the roof trusses. The chute leads to a conveyor running the full length of the building and carried by longitudinal truss frames resting on the bottom chord of the roof trusses; the conveyor has on top a carrying platform made of wooden strips so as to present a practically continuous floor. At either side of the longitudinal conveyor is a cross conveyor, spanning the space from the center of the building to the side walls, and having its carrying platform at a lower level than that of the main conveyor. These cross conveyors form each a self-contained structure, running on tracks extending the full length of the building (attached along the side walls and along the center conveyor trusswork). The system of conveyors thus covers the whole space of the loft, and permits transferring bags from the elevator to any desired point.

The operation of the whole arrangement is illustrated in Fig. 1. The laborers in the car toss the bags into a stationary rack placed in the path of the projecting arms carried by the elevator chain. These projecting arms are so spaced as to pass between the bars of the rack, and they pick up the bag and carry it to the top of the building. Here the bags fall into the chute, down which they slide to the longitudinal conveyor, which carries them along to any desired point. The bags are unloaded from the conveyor by inclined guideboards, which may be fastened at any point, and which shove the bags off onto a short slide leading to the cross conveyor. From the latter they are in turn unloaded by another guideboard at the point desired, and by way of a hinged skidboard they slide to their place in the stack of bags. The only manual labor that remains to be done is to slew them around into proper stacking position.

The feature of difficulty in the design of this plant was to so construct the horizontal conveying platforms that the bags could be successfully slid over the side by the stationary guideboards without risk of catching and tearing. Its successful solution makes the plant of particular interest to engineers having to solve conveying problems in which the handling of material in bags is involved. We therefore illustrate this portion of the equipment in some detail. Fig. 2 shows the end portion of the conveyor with a guideboard in position upon it. Two light steel truss frames running longitudinally rest on the bottom chord of the roof trusses. Attached to the top longitudinal angle of each of these frames is a Coburn track, in which roll wheels attached by hanger pieces to the conveyor chain. The latter, in turn, carries on malleable-iron shelf-blocks the wooden strips that compose the platform of the conveyor. The construction is shown in detail in Fig. 3. Each pair of platform strips also carries horizontal guidewheels which maintain its alinement by bearing against a longitudinal angle adjacent to the roller-track. The carrying wheels of the conveyor chain also support the chain on its slack or return side, bearing for this purpose on a longitudinal shelf angle attached to the lower chord of the truss frame.

Fig. 2 also shows the face of the guideboard. It is fitted with projecting strips of wood running along the face and pitching slightly upward toward the discharging end of the board, the board itself leaning backward a little. The whole construction is intended, in connection with the smooth horizontal surface of the conveyor platform, to prevent the bags being drawn under the guideboard when they strike it, and to discharge them in proper manner upon the skidway.

The longitudinal conveyor is in two sections, as will be noticed from Fig. 1. This was necessary because the building makes a slight angle near the point where the bag-elevator is located.

The whole machinery is driven by five 5-HP. C. & C. electric motors, one each being provided for the bag-elevator, the two sections of the longitudinal conveyor and the two cross conveyors. It has been found, however, that the total power required to run the machinery is only 6 HP. at the maximum rate of work yet demanded of the plant handling 250 bags per hour. The builders think it would easily handle double that number.

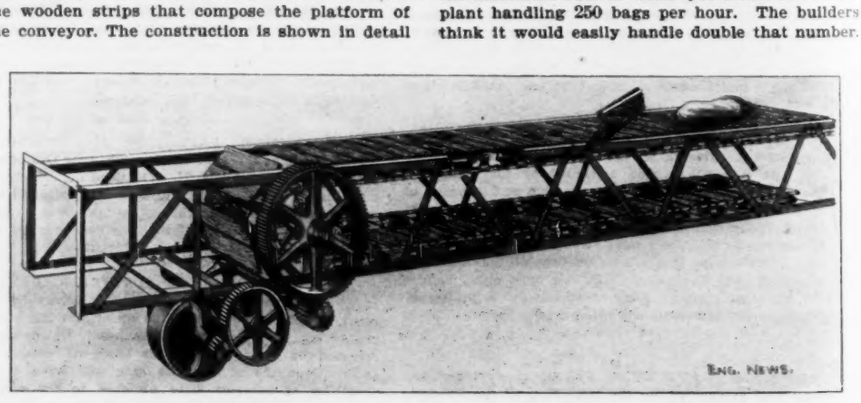


FIG. 2. VIEW OF END PORTION OF CONVEYOR WITH UNLOADING GUIDEBOARD.

This conveyor system was installed during the last summer, and has been completed only a few months. It is said to be working perfectly. From its successful operation the builders have concluded that the construction, the essential features of which have been patented, can be applied to handle any kind of material in bags or similar packages.

BITUMINOUS MACADAM PAVEMENT.*

By Fred J. Warren.†

It is well known that all bituminous pavement wearing surfaces are in fact artificial stone surfaces—the bitumen or asphalt being used to bind particles of stone or sand together. By far the greater bulk of the surface of the ordinary asphalt pavement is sand, and the names "asphalt pavement," "tar pavement," or "bituminous pavement" are misnomers, and simply convey in a very general way the nature of the cementing vehicle.

The principle on which the bituminous macadam pavement wearing surface is combined, is the reverse of the principles on which the ordinary asphalt pavement is built. In the present asphalt or tar pavement the bituminous cement is used to support fine mineral grains, such as sand, which in themselves have no firmness to sustain traffic, in such a way that the fine mineral grains will be held or supported by the bituminous cement so that the mortar or mastic will, at all atmospheric temperatures, sustain the weight of traffic, and, at the same time, resist abrasion.

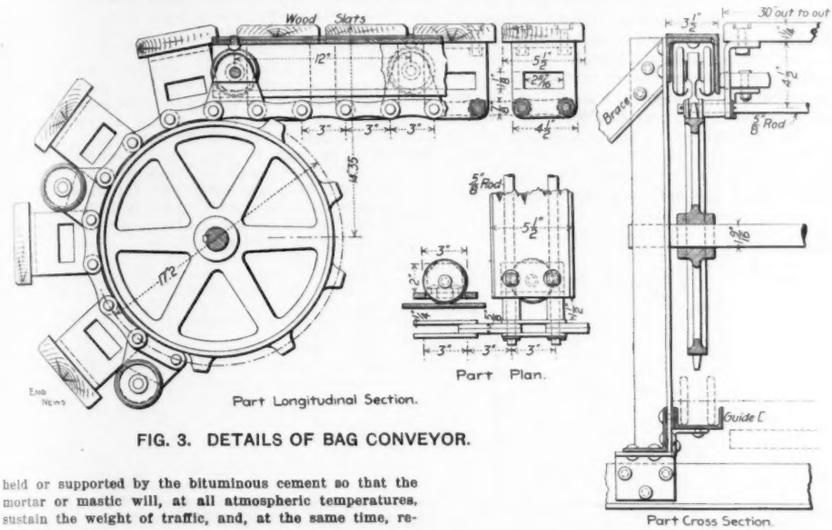


FIG. 3. DETAILS OF BAG CONVEYOR.

The bituminous macadam is built on the principle that, independent of the bituminous cement, relatively coarse and fine mineral grains should be combined in such a way as to have a firmness in themselves to sustain the weight of traffic. The bituminous cement is supported or held in place by the proper arrangement of stone particles as to size. The bituminous cement is used solely for the purpose of preventing attack on the stone from water and weather, and to bind the particles together sufficiently to prevent abrasion from traffic at all atmospheric temperatures, and, at the same time, provide an elastic bituminous cement or cushion between the mineral particles which will deaden the jar and prevent the wearing effect caused by the friction from the movement of its integral parts.

The life or efficiency of either pavement depends largely upon the skill and care with which the various elements of the wearing surface are selected and combined, but I believe it is possible to select and combine the elements on the principles of my theory or as practiced in the bituminous macadam pavement, so that the pavement will have several times more life than when constructed on the asphalt theory, and I feel much more certain that over 95% of the causes of failure can be overcome by the adoption of the bituminous macadam principle.‡

The pavement being described under the name of bituminous macadam is a patented combination of bitumen and mineral particles. It is being laid at a less price than asphalt or brick in New England. Its actual cost of construction is not materially different from the actual cost of constructing an asphalt pavement, but the price to cities is much lower on account of the commercial policy of those controlling its introduction.

The pavement has been laid in Pawtucket, R. I.; Holyoke, New Bedford, Cambridge, Lowell and Brockton, Mass.; Salem, N. J., and Charleston, S. C. It enters into competition with every other form of pavement. It has already been ordered on ten miles of streets in various sections of this country and Canada, for work to be done next year, and is now being considered on miles of streets in all sections of the country from the Pacific to the Atlantic.

Before it was actually laid, the only undeveloped theory entering into the construction was: "Can coarse particles of stone when used near the surface of a bituminous pavement be held in place so they will not chip out under traffic?" The most trying time to test this question is when the surface is new and has not had the advantage of compression by traffic. In no case has any individual stone slipped out of the surface in any of the seven cities where it has been used.

The ordinary method employed in its construction is to assume that a natural foundation thoroughly rolled with a heavy road roller, furnishes a solid subbase; that a solid base of 4 ins. of 2 to 2½-in. stone will, after thorough compression with a 15 to 20-ton roller, provide an ideal foundation for a waterproof surface, and will provide drainage to moisture accumulating from the surrounding ground. If more drainage is necessary, drains rather than extra foundations are advisable. The stone is better if very hard, but this is not so important in the foundation as in the top.

On top of the stone foundation is spread or sprinkled a coating of specially prepared thin bituminous cement which enters the minute crevices of the surface of the stone and permits the stone in the foundation being firmly held together with the waterproof cement which is afterwards freely used over the surface of the foundation. This waterproof cement is thus enabled to grip onto the stone permanently and, being of a hard pitchy nature of a grade of flexibility that will bind the surface of the foundation firmly in place, it makes the foundation itself rigid before the wearing surface is rolled in.

On top of the foundation thus prepared is spread a layer of the wearing mixture, which should have a thickness of about 2 ins., after its maximum compression. This mixture is a carefully prepared combination of 1 to 2-in. stone, having voids filled with receding sizes to a dust or powder of stone. Some sand may be used to aid in filling voids when necessary.

The mineral or stone part is dried and heated in a modern dryer and is then separated by screening with rotary screen into its sizes varying from fine dust (which is less than $^1/_{200}$-in. in diameter), to the largest size used. The several sizes of stone are then mixed in predetermined proportions, so as to reduce the voids to about 10%, in a modern "twin pug" steam power mixer, and the hot bituminous cement is added in the mixer in sufficient quantity to not only coat every particle and fill all of the remaining voids, but with enough surplus to furnish to the mixture after compression, a rubbery and slightly flexible condition.

The mixer makes 75 revolutions per minute, and every particle of mineral is coated in about 15 secs., but the mixing is continued about two minutes to provide absolute uniformity of distribution of bitumen and mineral. The whole is dumped by gravity into wagons and hauled to the street where it is spread in the same manner as an asphalt pavement. It is then rolled with a 15 to 20-ton road roller, which gives many times as much compression to the inch run as the ordinary asphalt roller.

After a thorough and continuous rolling there is a little honeycombed appearance to the surface where coated particles of stone come together, but the body of the mixture on being broken shows denser under the magnifying glass than any bituminous wearing surface that has heretofore been used.

Good rolling is an essential feature, as it assists to place the particles where they belong, and continued rolling forces out the minute air bubbles and forces the surplus bitumen into the fine voids, leaving the body of the surface so dense that it cannot be rutted or displaced by traffic. It also adds to the life of the bituminous cement by protecting it from the action of exposure to the elements in minute semi-detached particles. The rolling should commence as soon as the surface is spread, and it is advisable that one heavy roller should not be required to do more than 1,000 sq. yds. of surface per day.*

On top of the surface thus made, partly to heal and seal the surface from attack, and partly to hold and help make a practical wearing surface, there is poured and rubbed into it all of the quick-drying bituminous cement that it will take. This leaves the surface as sticky as if freshly painted.

On this surface is spread a coat of fine stone chips which adhere to the bitumen on the bottom and present a rough gritty surface to travel. The rolling of these rough chips into the surface has the effect of putting the pavement under greater pressure, and forces as much stone into the surface as it can possibly receive, thus making it more gritty and suitable for travel.

The above method gives an ideal road surface, and with traffic and wear it will always maintain a large part of the roughness of a perfect macadam road as compared with the smoother and polished surface of the asphalt. It is relatively as smooth as asphalt, yet the coarse particles of the surface hold moisture and dust longer, and the pavement will always be less slippery, less dusty, and can be made more durable than any bituminous pavement previously laid. Under considerable traffic, I believe, it is as durable as a block-stone pavement made of the same stone. While the coarse stone in the pavements prevents cutting up under traffic in summer, which asphalt pavements frequently do, yet the increased flexibility of the bitumen and the larger amount used, as compared with the voids to be filled, provides a surface more elastic and not as hard on horses, while fully as pleasing for pleasure driving.

The click from the horses' hoofs is much reduced as compared with asphalt, and the pavement is one of the most noiseless in use. This is especially noticeable in cold weather, when all bituminous pavements are the hardest and most resonant.

From the practical standpoint of an engineer, it can readily be seen that the rigid stone particles permit of: (1) The reduction of voids; (2) the use of a softer bituminous cement; (3) a heavier coating of cement around each grain.

Each of these self-evident conditions will, in themselves, more than double the life and service of the bitumen itself. If the pavement fails it will be from other causes than the common reasons for failure of asphalt pavements as at present constructed, but might be from such causes as the following: (1) The crushing or grinding of a poor quality of stone under traffic; (2) carelessness in not properly placing the various sized elements of stone; (3) improper equipment and supervision induced by inconsistent economy.

The selection and method of preparation of bituminous cement used has naturally great relation to the life of any pavement. Bitumen, as is well known, passes by almost insensible degrees from liquid to solid form, and may be tempered to any consistency. The softer the temper of any given quality of bitumen, the longer its life under any given amount of exposure. The softer the temper of the cement, the lower the melting point and the greater its flexibility at any temperature lower than its melting point. The length of time any given grade of bitumen will remain flexible and fill its office depends largely if not wholly, upon the kind and conditions of exposure.

With natural hard bitumens or pitches, the process is to "cut back" the natural material with oil of various classes, to produce the softness desired. With natural soft bitumen the process is to extract a part of the natural softening oil.

All other things being equal the process of cutting back the bitumen injures its physical quality. With some forms of bitumen, however, it may be advisable to substitute a good permanent oil or softening flux, for an inferior oil present in nature. The general practice in "cut back" cements is to remove an oil of great value commercially, and of value to the cement, and substitute an inferior oil of little commercial value. It is seldom that it occurs that any crude bitumen, as it is found in nature is in the best state of flexibility for use for any purpose. It is sometimes used in its crude commercial state, but it is generally deficient in some one or more essential properties.

*Abstract of a paper read before the Boston Society of Civil Engineers, Jan. 8, 1902.

†143 Federal St., Boston, Mass.

‡Attention should be called to the fact that so-called "tar macadam" is built on the principles of the ordinary tar concrete, with the exception that stone is used instead of gravel for the foundation, and only about the same quantity of surface mixtures is used as in the ordinary tar sidewalk. An effort is made to force the surface into the foundation by rolling with a heavy roller. It is an imperfect method of accomplishing a result. Its efficiency is largely determined by the extent that the surface mixture is forced into the base, and the life is also largely determined, as are all other bituminous pavements, on the proper selection of the elements making the surface. I do not see that the pavement offers any advantage or is any different in principle or wearing properties, over what is known as tar concrete, except that a heavier roller is used in the compression. The "tar macadam" process does not overcome the principal causes of initial failure.

*Great care should be exercised in heating the stone or mineral parts, as overheating the stone will cause rapid change in the softness or ductility of bituminous cement, each particle of stone being coated with a layer of less than $^1/_{500}$-in. in thickness; the effect of high heats in this condition of exposure is very rapid on the cement. This condition is not so important as in the asphalt pavement, as the coating of the cement is heavier, and it is used in a softer form and therefore has more life to lose, before it becomes inefficient. It is nevertheless important, for the cement is prepared with an allowance made for the normal change in making the pavement, and if the change is abnormal, the physical differences may affect the life of the work.

In order to maintain uniformity and enable one to improve and perfect any bituminous pavement, it is quite essential to have recourse to a chemical and physical testing laboratory, and to record all conditions present. Such a laboratory should not only examine materials to be used, which examination justifies an opinion of their conbination or use, but, after a mixture of combination has been determined upon a sample should be taken daily, or at frequent intervals, and it should be separated into its parts and the actual conditions present in the mixture, as it is actually laid, should be carefully recorded, and the exact location where the particular sample is taken, should be noted.

This record acts in affecting the pavement in important ways. It gives a sure test of whether instructions are being followed, and makes every employe careful, for carelessness will surely be detected under this system.

It also provides a record of the exact conditions present, as the pavement mixture is actually laid, as against and to be compared with, the record of the exact kind and quality of the commercial materials directed to be used. This system has made it possible to lay fairly good bituminous pavements out of relatively poor bituminous cement, and under principles which have proven deficient. The record is an invaluable aid in measuring the change in the physical condition of the wearing surface, and the bitumen itself under exposure to weather.

It is far easier and more practical to measure the changes that take place by physical than by chemical tests. It becomes important, however, to know the nature of the bitumen and so use it as to prevent the changes from taking place.

The bitumens vary a great deal in their crude state in many different and varying physical and chemical properties. The essential chemical differences that can be detected are varied proportions of oxygen, hydrogen and carbon. The presence of varying quantities of non-bituminous substances such as free carbon, sand, clay, loam, vegetable matter, lime, soluble salts, acids, sulphur, etc., can be detected by analysis and may indicate the danger encountered in its use. The relation of the atoms of oxygen, hydrogen and carbon to each other, as it affects the physical condition of the bitumen, has never been definitely determined. It is known, however, that the process of hardening is the liberating of a larger part of the hydrogen atoms than of the oxygen atoms, or the taking up of oxygen from the air, which in itself brings about a rearrangement of the atoms and a consequent change in the physical properties of the cement or bitumen itself.

The physical condition does not change except on exposure to the elements, and as stated, the life and stability of a given bitumen depends entirely on the quantity of atoms exposed and on the extent of the exposure. In solid bulk in nature the change is so slow as to take centuries or ages to change a soft bitumen to a hard one, and the presence of oils are often indicated by the outcropping of asphalt or tar in the surface.

The important physical tests as applied to bitumen are relative only. The important tests are for flexibility, viscosity, brittleness, ductility, adhesiveness, range of temperature between its liquid and brittle point, aging effect of a given amount of exposure, amount of volatile oils, effect of water on exposure.

The estimation of life should, of course, be considered in connection with tests made on the crude material used, on the cement itself, and the completed pavement wearing surface, and can only be considered in connection with a large volume of tests made on pavements at various stages of their life. The results of such tests mean nothing to anyone who has not in practice become familiar with the detailed conditions present in a large quantity of good, medium and defective work.

COMPARATIVE TESTS OF COAL AND CRUDE OIL AS FUEL.

An interesting series of tests on the comparative results obtained with coal and Texas crude oil as fuel under a boiler was carried out some weeks ago by Prof. J. E. Denton, of Stevens Institute of Technology, Hoboken, N. J. The tests were arranged at the instance of several large power-users in New York city by Mr. H. M. McDonald, of the Export Oil & Pipe Line Co., of Beaumont, Texas. Prof. Denton's report on these tests* has just been made public by the latter company.

While the tests were primarily arranged with a view to determine the economic fuel value of the oil as compared with coal, care was taken to note everything connected with boiler-firing that might have a bearing on the practical value of oil compared with coal; labor of firing, danger from the storage or use of the oil, effect of sulphur in oil, were some of the matters considered. On this account the main conclusions of the report will without doubt interest engineers in general, particularly so since the results of Prof. Denton regarding comparative costs were generalized by him to cover the case of different kinds of coal and different prices of the same. The following is an abstract of the essential parts of the report.

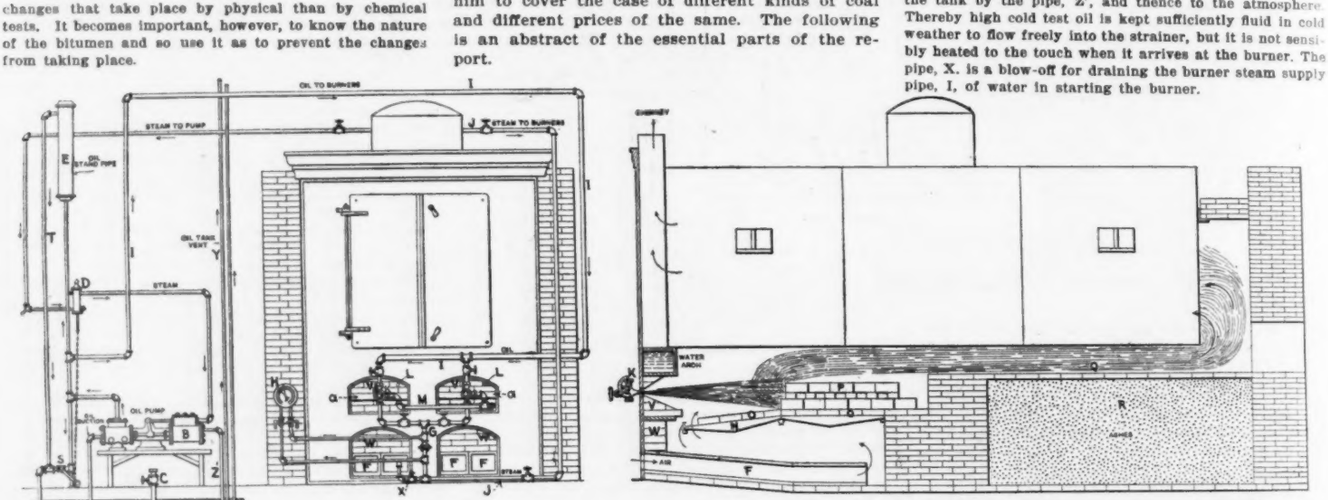


FIG. 1. OIL-BURNING BOILER FURNACE FITTED WITH WILLIAMS' STEAM-JET OIL BURNER.

The boiler tested is one of a battery of three horizontal return tubular boilers, each 72 ins. × 18 ft., in the boiler room of the American Ice Co.'s plant, at 544 W. 19th St., New York city. The boiler in question had been fitted for the use of oil about a year and a-half ago, by the International Gas & Fuel Co., of Chicago. The whole oil-burning installation is shown in front elevation and longitudinal section in Fig. 1.

Four ducts of hollow tile, F, 10 × 6 ins., were laid in the ash pit extending nearly to the bridge wall, and the ash-pit door openings closed by brick work, W, around the outer ends of the tile. The forward bearer of the grate bars, N, was dropped, about half of the forward set of bars removed, and a course of fire brick, O, laid with fire clay over the whole upper surface of the grates, so that air entering through the tile could flow back along the outside of the latter and then around and up between the front end of the grate bars through an area a little greater than that of the aggregate cross section of the tiles. A checker work, P, of about fifty loose fire brick was built over the grates, the space back of the bridge was filled with ashes, R, flush with the top of the bridge wall, and a single-course floor, Q, of fire brick laid over the ashes. An iron bar, a, was bridged across the middle of the fire door opening, and the remainder of the latter closed with fire brick, V, flared on the inside, a small opening, L, being left for applying the torch to the burners. Into the iron bar across each door was screwed the burner, K.

The burner used was the Williams' patent oil burner; it is shown in detail in Fig. 2. The burner has three supply openings; oil enters at the top through opening b, the flow being regulated by handle d of cock c; steam enters at e and flows through the passage of the needle-valve f, meeting the falling drops of oil and vaporizing them; the suction produced by the flow of steam draws air in through opening i, this air being drawn from the back of the ash-pit through a tile duct built on top of the grate surface. Thus, a heated gaseous mixture of oil, steam and air is blown through the forward opening of the burner into the furnace, and meets with the partly-heated air drawn from the ash-pit up through the forward and open part of the grate.

The oil was stored in an iron tank, A, Fig. 1, 7 ft. in diameter by 5 ft. deep, sunk in the ground, into which the barrels, in which the oil was received, were emptied, from time to time, through the pipe, C. The top of the tank was closed, ventilation being afforded by the pipe, Y. A steam pump, B, drew oil from the tank through the strainer, U, by the pipe, Z, and delivered it to the stand-pipe, E. Thence it flowed by the pipe, I, to the burners, under a head of about 10 ft. The pump ran constantly, and delivered a surplus which flowed back to the tank through the pipe, T. The pump was provided with a device (this is a safety device required by Western Insurance rules), D, having a piston connecting by a chain with a cock, S, which automatically opened when the boiler was not under steam pressure so that the stand-pipe would be emptied of oil by the latter flowing to the storage tank. The steam exhaust of the pump passed through the tank by the pipe, Z', and thence to the atmosphere. Thereby high cold test oil is kept sufficiently fluid in cold weather to flow freely into the strainer, but it is not sensibly heated to the touch when it arrives at the burner. The pipe, X, is a blow-off for draining the burner steam supply pipe, I, of water in starting the burner.

The air entered the ash-pit tiles under the natural draft of the chimney, 70 ft. high by 42 ins. square, connecting to the boiler tested by a 40-in. flue about 30 ft. long.

In order to measure the steam consumed by the burners the opening in the flange union, G, on the steam pipe, J, was reduced to ⅜-in. by a diaphragm, and the pressure each side of this opening measured by the differential steam gage, H. After the tests the readings of the differential gage were duplicated while the steam flowing was condensed and weighed. The amount of oil consumed was determined by weighing the barrels before emptying them into the storage tank, and by means of a float in the latter operating over a scale which was calibrated for the tests. The feed water was measured by a reliable meter, made by the Neptune Meter Co., of New York, which was calibrated at proper intervals.

The boiler was regularly cleaned internally every ten weeks, and the period of the tests was at the middle of one of these intervals.

While the boiler was under test with oil as fuel, i. e., from Nov. 25, 1901, to Dec. 5, 1901, tests were made to determine the steam-raising power and the evaporative power of the oil-fuel, data as to obtainable capacity being derived from the same tests. The oil-burning apparatus was then removed and similar tests were carried out with the regular coal-fuel. It may be noted here that while the oil-burning apparatus was being removed, the boiler and furnace were carefully examined to note the effect of the oil on the exposed surfaces.

Each barrel of oil emptied into the storage tank was sampled, and a mixture of the samples tested; the results of this test were the following:

Specific gravity	0.920
Flash point	142° F.
Burning point	181° F.
Cold test	— 6° F.
Calorific value per lb. by oxygen calorimeter	19,000 B.T.U.

*The report may be had in pamphlet form by applying to Mr. H. M. McDonald, 100 Broadway, New York.

TABLE I.—Resume of Tests.

Dimensions of boiler: ft. diam., 18 ft. long; 100 tubes, [illegible] in diam.; grate surface, 45.5 sq. ft.	Beaumont crude oil. Night of Nov. 27.	Night of Nov. 27-28.	Night of Nov. 28.	Night of Nov. 28-29.	Night of Nov. 29.	No. 1 buckwheat coal. Dec. 12.	Dec. 13.
[illegible] hrs.	3.5	8	11	13	11	12	12
Duration, hrs.	146.9	112.7	189.7	138.0	220.1	92.6	119.1
Horse-power	87	86	86	86	86.5	84.5	86.5
Steam pressure (gage), lbs.	69	90	70	90	74	68	72
Feed temperature, degs. F.	374	390	398	370	425	389	396
Chimney temperature, degs. F.	Dry.	Dry.	Dry.	Dry.	Dry.	Dry.	Dry.
Quality of steam	.....	.....	.....	.....	.....	6.2%	6.2%
Moisture in coal.	.....	.....	.....	.....	.....	16.2%	18.0%
Per cent. of ash	.....	.....	.....	.....	.....	Once.	Twice.
Times fire was cleaned	.....	.....	.....	.....	.....	7.66	10.10
Coal per hr. per sq. ft. of grate, lbs.	.....	.....	.....	.....	.....	0.182	0.247
Per sq. ft. of heating surface, lbs.	.....	.....	.....	.....	.....	.....	.....
Oil per hr. per sq. ft. of heating surface, lbs.	0.181	0.135	0.226	0.163	0.263	.....	.....
Dry steam per hr.* per sq. ft. heatg surface, lbs	2.73	2.09	3.52	2.56	4.08	1.72	2.21
Heating surface per HP. sq. ft.	12.6	16.5	9.8	13.5	8.45	20.1	15.6
Total dry steam per lb. of fuel as fired.* lbs.	15.29	15.53	15.55	15.71	15.49	9.17	8.94
Per cent. of steam used by burner.†	3.6	3.1	4.8	3.5	4.8	.....	.....
Net lbs. of dry steam per lb. of fuel as fired.*	14.74	15.05	14.80	15.16	14.75	9.17	8.94

*From and at 212° F. †The steam used by oil pump was fraction of one-tenth of 1%, and it is therefore not considered.

Composition: Carbon	84.60%
Hydrogen	10.90%
Sulphur	1.63%
Nitrogen	0.00%
Oxygen	2.87%

The coal used was a high grade of No. 1 Buckwheat (anthracite) coal, being the same as was regularly used under the other two boilers of the plant. It contained, approximately:

Moisture	6.2%
Ash	11.6%
Composition: Carbon	77.5%
Hydrogen	2.9%
Sulphur	0.5%
Oxygen and Nitrogen	2.2%

The total ash in the fuel as actually fired was more than the amount given above, being from 16 to 18% of the total fuel.

The results of the whole series of tests, and the conclusions drawn therefrom in Prof. Denton's report, are set forth substantially as follows:

TIME REQUIRED TO RAISE STEAM.

Starting with the brickwork of the setting cold and the water in the boiler at 64° F., the time to raise steam to 85 lbs. pressure was determined to be: With oil, 59 mins.; with coal (the fire being started with a very liberal amount of dry wood) the corresponding time was, 1 hr. 17 mins.

EVAPORATIVE POWER AND CAPACITY OF BOILER.

The tests with the oil were made at capacities verying from 112 HP.—which was thought to be about the horse-power at which the boiler was operated in its regular use with coal—to 220 HP., which represented the limit of satisfactory air supply available from the draft power of the chimney with a wide-open damper. That is, up to 220 HP. there was sufficient air supply to prevent any appearance of smoke in the flame, or at the top of the chimney, but more than this horse-power caused curling streams of smoke to appear at the edges of the flame in the furnace, and a light gray vapor to be visible at the chimney top.

The tests with coal were made at 93 and 119 HP., the first amount being that demanded of the boiler when operated with its companion boiler under the steam damper regulation common to the regular regime of the factory, and the second amount being the greatest horse-power which could be obtained with the dampers wide open, and the companion boiler checked so as to allow the test boiler to take all of the load that it could.

The results of the tests are given briefly in Table 1. From the tests the following conclusions may be drawn:

1. For a range of from 112 to 220 HP. the total evaporation from and at 212° per lb. of oil varied from 15.71 to 15.29 lbs. of dry steam, and the burner consumption varied from 3.1 to 4.8% of the boiler output, so that the net evaporation ranged from 14.74 to 15.16 lbs. of water per lb. of oil. An excess of cold air probably caused a loss of evaporation for the smaller horse-powers, but for the 189 and 220-HP. tests there was no excess of the air necessary for complete combustion. Consequently for the two higher horse-powers the net evaporation of 14.8 lbs. of water per lb. of oil may be considered to represent the best economy that is to be expected from the use of the oil as a fuel with steam-jet burners.

The combustion of the oil by the burner was practically perfect. The boiler utilized about 78% of the heat of the fuel, which represents the best average boiler practice, and the percentage of steam consumed by the burners is a minimum for steam-jet burners.

2. The evaporation from and at 212° F. per lb. of coal was 9.17 and 8.94 lbs. of water for 93 and 119 HP. The coal afforded 11.6% of ash, and 14,680 B.T.U. per lb. of combustible when burned in oxygen in a calorimeter, which represents an excellent No. 1 buckwheat. The firemen were the regular employees of the ice company. They were skilful operators, and secured practically complete combustion of the coal. Considering that the coal was laden with 6.2% of moisture, and was consumed in the furnace to about 17% of ash, the evaporative results per lb. of wet fuel are excellent. They correspond to an evaporation of 11.79 lbs. from and at 212° per lb. of combustible, which affords the very excellent boiler efficiency of 77.9%.

Had the draft been sufficient to burn enough coal per hour to produce about 10 HP. per sq. ft. of heating surface, as in the case of the 189 HP. test with the oil—and as is commonly guaranteed in the sale of modern boilers—the boiler efficiency would probably be reduced on account of the greater velocity of the heated gases over the heating surface resulting in a higher chimney temperature, and hence the waste of a greater proportion of the heat of combustion. Such reduction of efficiency would probably have made the evaporation per lb. of wet coal only about 8.5 lbs. But had the percentage of moisture in the coal been the average amount, or 3%, the evaporation would have been about 8.75 lbs.

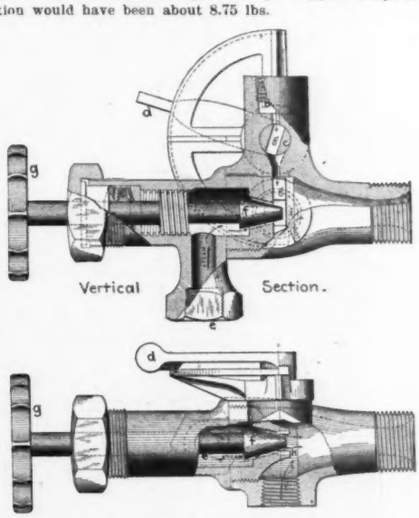


Fig. 2. Details of Williams' Oil Burner.

3. The comparative fuel costs of coal and oil for the particular conditions of the ice factory where the tests were conducted are therefore as follows:

(a) For producing the horse-power required by the factory, or 1 HP. per about 20 sq. ft. of heating surface, with the moisture and ash as found:

Weight of oil per gallon	7.66 lbs.
Evaporation per lb. of wet coal from and at 212°	9.17 "
Net evap. per lb. of oil from and at 212°	15.1 "
Ratio of oil to coal $\frac{15.1}{9.17}$ =	1.65
No. of barrels oil equivalent to 2,240 lbs. of coal	4.23
Price, coal per long ton, no haul or ash removal	$3.00
Equivalent price of oil per bbl. of 42 U.S. gallons	$0.71

(b) For producing horse-power upon the commonly guaranteed basis of 1 HP. per 10 sq. ft. of heating surface, and with an average percentage of moisture and ash in the coal:

Evaporation per lb. of wet coal from and at 212°	8.75 lbs.
Net evap. per lb. of oil from and at 212°	14.8 "
Ratio of oil to coal $\frac{14.8}{8.75}$ =	1.69
No. of barrels oil equivalent to 2,240 lbs. of coal	4.12
Price, coal per long ton, no haul or ash removal	$3.00
Equivalent price of oil per bbl. of 42 U. S. gallons	$0.73

4. The comparative fuel costs of coal and oil may further be summarized, on the basis of the tests, for the different qualities of coal in common use in the United States, and for different prices per ton for any such coal. Table II. gives this summary. In this table different prices are assumed for a ton of coal, and the price can be read from the table which may be paid for a barrel of oil to produce steam as economically as with coal. For example, at $3.00 per ton of coal the price of oil per barrel of 42 U.S. gallons to obtain the same horse-power as from coal by the same expenditure of money for fuel is:

For western bituminous	$0.85	Best semi-bituminous:	
No 1 buckwheat & pea.	.73	Mechanical stokers	
Pittsburg bituminous...	.67	& patent furnaces:	
Best semi-bituminous:		10% ash	$0.60
Hand fired	.64	5% ash	.58

LABOR SAVING BY USE OF OIL.

It is probable that one fireman can attend to 30 oil burners of 100 boiler HP. each. This fact will permit a saving for firing labor in hand-firing plants of more than about 500 HP. capacity, and of more than about 1,000 HP. capacity in mechanical stoker plants. This saving will, under average conditions of coal and wages, amount to about 15 cts. per ton of coal used for power in excess of 500 HP. in hand-fired boilers, and in excess of 1,000 HP. with mechanical stokers.

There will also be a saving in ash-handling labor, or helpers in the fireroom, which will probably be about one-fourth of the above amount. In cities the cost of carting away ashes will be saved. This amounts to about 10 cts. per ton of all coal used. There will also be a saving in furnace repairs, which may amount to 2 cts. per ton of coal.

The cost for handling the oil will probably be less for machinery than for coal, but much more for ground space, required for underground storage tanks.

DANGER FROM USE OF OIL.

Experiments with samples of the oil used for the evaporative tests show the following results regarding its inflammable qualities:

(1) That oil spilled to form a liquid pool, at ordinary temperature, about a boiler room, would not be ignited by a lighted match, or a hot coal, falling into it, and that even a lighted torch would have to be in contact with it for several seconds before it would inflame.

(2) That up to 100° of temperature the oil did not vaporize sufficiently to make a burning mixture of the air above the oil in a half-filled fruit jar.

(3) That its volatility does not give rise to inflammable vapor until it is heated above 142° F. Then, as the vapor is essentially identical with that given off by gasoline at ordinary temperatures, all the well-known safety precautions for the storage and handling of the latter substance apply to the oil, although the rapidity with which vapor is given off per square foot of surface is much less with the oil than with gasoline.

It was suggested during the evaporative tests that the

TABLE II.—Comparative Costs of Oil and Coal.

Items.		Bituminous coals mined west of Ohio, and used in Western & South western states.	Small sizes of anthracite—Culm.	No.3 Buckwheat or barley.	No.2 Buckwheat or rice.	No.1 Buckwheat and pea.	Pittsburg bituminous used in mills of Pennsylvania & on Great Lakes.	Semi-bituminous: Atlantic Oc'n traffic; mills of Eastern and Middle states—Mechanical stokers and patent furnaces*—Hand-fired.	Ash, 10%.	Ash, 5%.
1. Pounds evaporation per lb. wet[3] coal, from and at 212°, at about 10 sq. ft. of heating surface per boiler HP.		7.5	7.75[2]	8.25[2]	8.50[2]	8.75	9.50	10.00	10.50	11.00
2. Pounds evaporation per lb. of Beaumont oil from and at 212°, at about 10 sq. ft. of heating surface per boiler HP.		14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8
3. Ratio of evaporation of oil to coal = Line 2 ÷ Line 1 = R		1.97	1.91	1.79	1.74	1.69	1.56	1.48	1.41	1.35
4. No. barrels oil = to 2,240-lb. ton wet coal = 2,240 ÷ (322[1] R) = N		3.54	3.64	3.90	4.00	4.12	4.46	4.70	4.94	5.15
Equivalent price of oil per barrel of 42 U.S. gallons = $P_o \div N = P_o$.										
5.	$1.00	$0.29	$0.28	$0.26	$0.25	$0.25	$0.23	$0.21	$0.20	$0.19
6.	1.50	.43	.41	.39	.38	.36	.34	.32	.30	.29
7. Price of coal,	2.00	.56	.55	.51	.50	.49	.45	.43	.40	.39
8.	2.50	.71	.69	.64	.62	.60	.56	.53	.50	.40
9. per ton of P_o	3.00	.85	.82	.77	.75	.73	.67	.64	.60	.58
10. 2,240 lbs.	3.50	.99	.96	.90	.87	.85	.78	.75	.71	.68
11.	4.00	1.13	1.10	1.02	1.00	.97	.90	.85	.81	.77
12.	4.50	1.28	1.23	1.16	1.13	1.09	1.01	.96	.91	.87

*Mechanical stokers and patent furnaces introducing air over fire.
[1]Weight of oil per gallon = 7.66 lbs.; weight of oil per barrel of 42 U.S. gallons = 322 lbs.
[2]These figures are net evaporation after allowing for steam consumed to produce the forced draft necessary for burning the fuel.
[3]By "wet coal" is meant coal containing 3% of water.

accidental opening of the oil valve of the burner, so as to cause a large excess of oil in proportion to the steam jet supply, might cause some sort of explosion in the furnace.

The maximum draft of the chimney supplied only air enough for the perfect combustion of as much oil as corresponded to about one-half of the full opening of the oil valve. The oil valve of one burner was suddenly changed from this setting to wide open twice on the last day of the use of oil, and the only effect was to fill the furnace with thick smoke, no explosion or excess of pressure in the furnace occurring.

SULPHURETED ODOR FROM OIL.

The presence of sulphur in the oil gave rise to a strong sulphureted hydrogen odor from the storage tank. No odor, however, resulted from the combustion of the oil.

EFFECT OF SULPHUR IN THE OIL UPON LIFE OF BOILERS.

Excellent Pittsburg coal contains as high as 1.7% of sulphur, and its use affords the average period of the life of boilers. In generating equal horse-power with such coal the amount of sulphur in the furnace gases will be the same with the oil as with this coal, if the sulphur in the oil is as high as 2.6%, which considerably exceeds the proportion of sulphur in the oil. . . . In view of these facts there need be no apprehension of shortening the life of boilers by use of the oil.

EFFECT OF THE OIL ON THE EXPOSED SURFACES.

As noted above, the boiler and furnace were examined at the time the oil-burning apparatus was removed. This was after tests with oil had been conducted during a period of ten days, and after a total of 117 barrels, or about 38,000 lbs. of oil, had been consumed. No trace was found of any action of the oil on the boiler. There was no oily matter on the internal brickwork, nor any discoloration of the latter, and there was less than 1-64-in. of soot in the tubes, which had been swept clear of coal ashes at the beginning of the use of the oil.

ELECTRICAL MACHINERY IN THE POWER STATION AND SUBSTATIONS OF THE MANHATTAN RY. CO.

On Jan. 9 the first electric train was put in service on the Second Ave. line of the Manhattan (Elevated) Railway Co. in New York city. Current is supplied from the new power house of the company at 74th St. and East River, where the first power unit is now in continuous operation. The installation of the remaining units and accessory machinery is progressing rapidly, and in the course of a few months the whole generating plant will be ready for operation and the trains on all lines of the company will be run by electricity.

We present herewith illustrations of the most important machines in the power house and substation equipment. The main power house is to contain eight separate engine-generator sets, all alike. Each set consists of a double compound engine of 8,000 HP. normal and 12,000 HP. maximum capacity, driving an alternating-current generator rated at 5,000 K-W. normal and 7,500 K-W. maximum output. Both the steam element and the electrical element of one of these units exceed in size anything previously produced in their respective lines. The steam engines were designed and built at the Allis works of the Allis-Chalmers Co., at Milwaukee, Wis., under the direction of Mr. Edwin Reynolds. The alternators were designed and built by the Westinghouse Electric & Mfg. Co., of Pittsburg, Pa., who were also the builders of the great generators at Niagara, which were, before the construction of the present machines, the largest in the world.

Fig. 1 gives a general view of one of these units. Two compound steam engines are arranged, one at each end, upon a horizontal shaft resting in two bearings. On this shaft, between the bearings, is carried the revolving field of the alternator, 32 ft. in diameter and weighing 185 tons. This revolving field supplies all the necessary flywheel effect. The two engines are, except for their connection to a common crank shaft, entirely distinct.

The steam engines present many peculiarities in design, all developed from the unusual conditions to be met. The low-pressure cylinder at each end of the shaft is placed vertically over the center line of the shaft, securing for the large moving masses the recognized advantages of this construction. The high-pressure cylinder is placed horizontal, with its connecting-rod acting on the same crank-pin as the low-pressure rod. The cranks at the two ends of the shaft are placed 135° apart. It will be noted that the arrangement as described gives great compactness, perfect symmetry and a very uniform turning moment. The principal data in regard to the engines are the following:

Diameter of high-pressure cylinders	44 ins.
Diameter of low-pressure cylinders	88 "
Common stroke	60 "
Speed in revs., per min.	75
Normal capacity of one unit	8,000 HP.
Diameter of piston rods	8 ins.
Length of connecting rods	5.4 cranks.
Crank-pin, bearing	18 x 18 ins.
Crosshead pin, bearing	12 x 12 "
Diameter of shaft	37 "
Length of shaft	25 ft.
Steam pressure	150 lbs.

The cylinders of the engines are not steam-jacketed, but the valves in the low-pressure cylinders are placed in the heads, giving here a partial steam-jacket effect. The regular Reynolds-Corliss valve gear is used. The high-pressure cylinders have each a single eccentric, but on the low-pressure cylinders separate eccentrics are used for steam and exhaust valves.

Between the high and low-pressure cylinders is placed a reheating receiver, which is attached to the frame vertically and below the cylinder, on the side not shown in the figure. The receiver of each engine contains 773 sq. ft. of reheating surface in the form of 2-in. copper pipe, in which live steam circulates. The low-pressure cylinders exhaust through 30-in. pipes (shown in Fig. 1 running vertically down the side of the frame), which join below the floor into one 40-in. exhaust main leading to the condenser. Each complete unit has a single condenser, a Worthington jet condenser, with separate air and circulating pumps driven by a geared direct-current motor.*

Fully as remarkable as the engines are the immense alternators. Running at 75 r. p. m. they produce three-phase alternating current of frequency of 25 cycles per second at a pressure of 11,000 volts. The peripheral velocity of the revolving field of 7,540 ft. per min. required great mechanical strength, and the high voltage and output called for, together with the character of the load, made the electrical requirements also very severe.

Fig. 1 shows the general appearance of one of these generators. The rotating field is composed of laminated poles keyed to a cast-iron rim. Instead of spokes, two riveted sheet-steel disks form the web of the wheel, these being in turn held by a cast-steel hub keyed to the engine shaft. The field has 40 poles; the steel plates composing them extend across two poles each, breaking joint. They are dove-tailed into the cast rim and are securely bolted together. The field winding is composed of one layer of copper bar wound on edge, with the insulating material cemented in place between the turns. In order to secure greater heat radiating capacity, the edges of the bars are left exposed. Between every two adjacent poles a copper shield is wedged in, holding the winding in place and making the field surface practically continuous. These copper shields also serve the purpose of preventing distortion of the magnetic field, and thus tend to preserve constant the form of wave generated. To further this end, the shields have external lips that extend over the edges of the field poles, which are beveled off.

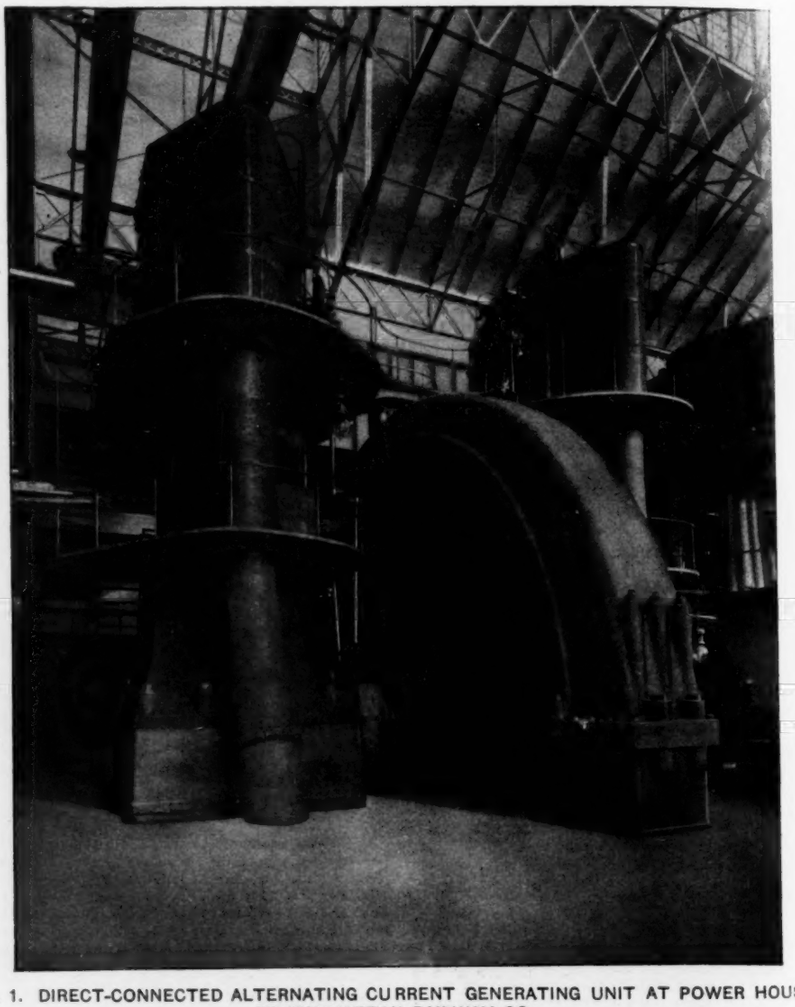


FIG. 1. DIRECT-CONNECTED ALTERNATING CURRENT GENERATING UNIT AT POWER HOUSE OF MANHATTAN RAILWAY CO.
Steam Engines Built by The Allis-Chalmers Co., Milwaukee, Wis.
Alternators Built by The Westinghouse Electric & Mfg. Co., Pittsburg, Pa.

*It may be noted here that all auxiliary machinery in the power house and substations, with the exception of the exciters mentioned below, is electrically driven.

The (stationary) armature ring is composed of six castings bolted together, two of which form the base of the ring. The core of the armature is built up of thin steel plates clamped to the ring castings. The armature winding consists of copper bars placed in slots in the inner face of the core. There are four slots per phase per pole, and three bars are placed in each slot. The winding is of the star type and is so arranged that adjacent end-connectors have only small differences of potential.

The normal exciting current in the field of each alternator is approximately 225 amperes at 200

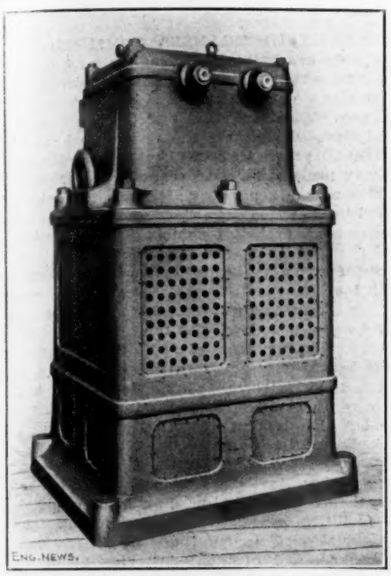


Fig. 2. Transformer in Substation of Manhattan Railway Co.

volts, but the excitation can be increased to take care of a 50% overload and a power factor of 0.90. The field insulation was tested with an alternating pressure of 2,500 volts for a period of 1 min. The insulation of the armature conductors was subjected to a puncture test of 25,000 volts alternating potential for a period of 30 mins., or 30,000 volts for 1 min., or 35,000 volts for 1 sec.

In the design of these alternators it was sought to maintain a wave form as near a true sine curve as possible at all loads. The adoption of many slots per phase tends to avoid the production of harmonics, which, in view of the number of large rotary converters to be used in the system, is an important matter in its effect on the regulation. With non-inductive load the electrical efficiency of one of these alternators should be 90% at quarter load, 96.5% at full load and 97% at an overload of 25%. When operating for 24 hours under full rated load, the maximum rise in temperature in any part of the machine should not exceed 35° C.; operating upder 25% overload for the same length of time, the rise should not exceed 45° C. with non-inductive load.

It may be mentioned here that the alternators were shipped in parts from the works at Pittsburg, special cars being required for this purpose, and were erected complete for the first time on their arrival at the power house in New York.

The exciting current for the main generators is furnished by a battery of four separate steam-driven exciter dynamos of 200 K-W. capacity each. The engines driving these dynamos are tandem-compound piston-valve engines of 300 HP. each, made by the Harrisburg Foundry & Machine Works. These engines use steam at the full pressure of 150 lbs. The exciter dynamos are the only auxiliaries in the whole system that are operated by steam directly.

The current of electricity leaves the large alternators at the power house at a normal pressure of 11,000 volts, and is distributed through underground conductors to the various substations. Rotary converters in the substations change the three-phase alternating current to direct current at 625 volts pressure for supply to the third rail. Large transformers are used to step down the current from its distribution pressure of 11,000 volts to about 390 volts, suitable for supply to the rotary converters.

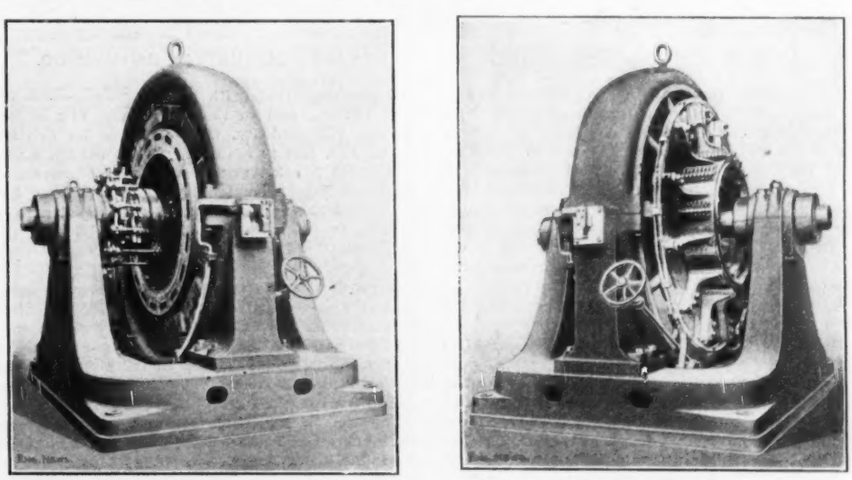
A view of one of the transformers is given in Fig. 2. They are of the regular Westinghouse type, cooled by a blast of air furnished by motor-driven blowers. To adjust for varying drop in voltage in adjacent sections of line supplied from the rotary converters of different substations, it is desirable that the ratio of transformation of the alternating current in the transformers may be varied; for this purpose loops are brought out from the primary windings of the transformers.

The transformers are arranged in groups of three, connected in delta; each such group supplies current to one rotary converter. These latter are the largest machines of their type that have ever been constructed. With a normal capacity of 1,500 K-W., or a maximum of 2,250 K-W., they change the alternating three-phase current of a frequency of 25 cycles per second at a potential of 390 volts, as supplied by the transformers, to direct current of 625 volts pressure.

Fig. 3 shows two views of such a converter; the left-hand view shows the alternating current side, the right-hand the direct current side. The general construction is seen from these views. The field has 12 poles of laminated steel; the pole-tips are beveled at the edges and fitted with copper shields. The field is compound wound, the series winding compounding the machine from 575 volts at no load to 625 volts at full load. The armature is of the slotted drum type, the poles being composed of steel disks forced upon a cast-iron spider. The armature winding consists of strap wound coils formed and insulated before being placed in position; the coils are held in the slots by fiber retaining wedges. The winding is of the parallel type, forming 12 circuits, and is cross-connected by balancing rings. The commutator bars are of hard copper insulated with mica. The difference in potential between adjacent bars will not exceed 12 volts. The normal speed of the converters is 250 r. p. m.

The rotary converters are started from the direct-current side. For this purpose current is supplied at each substation by a motor generator set. The latter is shown in Fig. 4.

The full load efficiency of the rotary converters is 95.75%; of the transformers, 97.75%.



Alternating Current Side. Direct Current Side.

FIG. 3. ROTARY CONVERTER IN SUBSTATION OF MANHATTAN RAILWAY CO.

The total weight of each converter is something over 50 tons. The machine stands 13½ ft. high and occupies a floor space of 10 × 13 ft. The total number of rotary converters in all the substations will be 26, supplied with current by 78 of the transformers described above. All these machines, as well as the motor generator sets, were built by the Westinghouse Electric & Mfg. Co., of Pittsburg, Pa., who also furnished, as before stated, the large alternators and the exciter dynamos at the main power station.

THE NEW YORK RAPID TRANSIT RAILWAY.

I.

Early History of Rapid Transit Enterprises in New York City.

EARLY UNDERGROUND RAILWAY PROJECTS.—The boldest of the various early proposals to build a rapid transit railway lengthwise of Manhattan Island was made in 1866 by the veteran engineer, Gen. Edward W. Serrell. At that time the population of New York city proper was but slightly over 800,000, and the population of the total area now embraced in the greater city of New York was something over 1,200,000. The street railway system of New York city proper in 1866 consisted of about 100 miles of horse car track, practically all of which was located south of 57th street. Taking these conditions into account, the proposition of General Serrell was a bold one; too bold, indeed, to be practicable, as subsequent events demonstrated. Briefly described, the plan of this well-known engineer was to build a road consisting of three lines, one above the other, from Battery Park to Kingsbridge, a distance as the crow flies of about 13 miles. One line was to be an elevated structure operated by steam for express passenger traffic; another was to be a subway line operated by steam for freight traffic, and the third was to be a surface line for way passengers.* This project seems not to have received serious consideration from capitalists. Its chief interest to-day exists in the fact that it anticipated both the elevated lines which came into actual being some ten years later, and the underground lines of the rapid transit subway now under construction.

Two years after General Serrell's proposition was made, a company known as the New York City Underground Co. secured a charter from the New York State Legislature which granted to it, in respect to route and capital investment, rather liberal powers looking toward the construction of an underground railway. This company made no attempt toward actual construction. About the same date a charter was granted to the Beach Pneumatic Underground Railway Co., empowering it to build a tunnel railway from Battery Park up Broadway to Harlem. This scheme deserves

*In a letter to us, dated Nov. 14, 1901, General Serrell makes the following statement concerning this project.—Ed.:

The plan contemplated two stories above ground and one below. The upper double tracks were for quick through trains, the middle double tracks were for local travel, with the rails over the cars as in a gun shop. This was to avoid accidents at street crossings. The two lower tracks were below the street level, and were to be used for freight. At the time it was projected it would have been a very good thing, and I am not sure but that this side of the Harlem it would have been as desirable as anything that could have been had. It only took two houses on each block and the expense would have been limited; the people picked up at each block on the middle system for short distances, and on the upper system from stations a mile and a half apart reached by elevators, could have been carried long distances quickly, in the open air and daylight, on the same ticket. We have yet to see anything better.

run its line through the city blocks and to rebuild the whole line with fireproof buildings, with the road occupying the basements 12 ft. below the surface of the streets crossed. The proposed line was from No. 1 South St., across Broadway near Rector St., and through the blocks near Broadway to 12th St. and University Place, thence diagonally across University Place and through the blocks near West Broadway to 59th St.

Following Mayor Hewitt's example, the succeeding Mayor of New York, Mr. Hugh J. Grant, inaugurated a rapid transit plan. Mayor Grant's ideas were embodied in a bill for a commission to lay out a route for a rapid transit railway east of Broadway. This commission, he proposed, should report to the Sinking Fund Commissioners, who, if they approved the route, should sell at public auction the right to construct and operate the road. This bill was introduced into the State Legislature on March 19, 1890. The plans of Mayor Grant met with the general approval of property-owners, but nothing ever came of them. Acting under the law of 1875, Mayor Grant then appointed a Rapid Transit Commission on April 9, 1890, which consisted of the following members: August Belmont, John H. Starin, Woodbury Langdon, William Steinway and Orlando B. Potter. These Commissioners were to determine when a rapid transit railway was to be built and what the motive power and the rates of fare should be. They were also instructed to fix the amount of the capital stock of the company to be formed for the construction and operation of the railway; they were to have absolute authority over the subscription books, and in fact there was scarcely anything connected with the proposed road in which they were not to be supreme. They, however, soon found that the law of 1875 did not allow the full exercise of such broad powers. It was impossible to go below City Hall with any tunnel line, and Broadway below Murray St., and also Park Row and Nassau St., were exempt from elevated railway lines; furthermore, no road, either elevated or underground, could be built along Fifth Ave., or Broadway, below 59th St., or Fourth Ave., above 42d St. Mr. Steinway at that time declared that engineering difficulties, particularly at Canal St., would prevent the construction of an underground railway. To relieve the Commission from these restrictions both Mayor Grant and Mr. J. Sloat Fassett caused bills to be introduced into the State Legislature, but both bills failed to pass. The Commissioners then talked of resigning, but finally decided to do the best they could under the existing circumstances.

They decided that nothing but a four-track road was worth considering, and considered the plan of buying a right of way for an elevated railway through the blocks. It was found, however, that the cost would be an insurmountable barrier to the success of any scheme of this sort. Finally they decided to abandon the notion of an elevated line, and to plan an underground system. Plans without number, and many of them without a trace of feasibility were presented to the Commission. At a meeting on Feb. 15, 1891, the old Arcade railway scheme was revived. Mr. Lawson N. Fuller then talked of a double-deck elevated railway, and other persons proposed a deep tunnel on the lines of the London "tube" railways. Next the People's Rapid Transit Co. came forward with a plan for a lofty masonry viaduct to run through the blocks from Yonkers, or, perhaps, Tarrytown, south to the lower end of New York city, with tunnel branches to New Jersey and Long Island. Meanwhile legislation was being secured which would put the rapid transit problem on a more practical basis for solution.

In January, 1891, the New York State Legislature passed an act providing "for rapid transit railways in cities of over one million inhabitants." The principal provisions of this act may be briefly summarized as follows:

(1) At any time after the act became a law the mayor of any city of over 1,000,000 population was empowered to appoint five persons who should be residents of the city and who should be commissioners of rapid transit. The commissioners thus appointed were to constitute a Board of Rapid Transit Railroad Commissioners in and for the city in which they were appointed.

(2) The Board of Rapid Transit Railroad Commissioners upon its own motion or upon the request of the local authorities was authorized to consider and determine whether it was for the interest of the public and of the city that a rapid transit railway be constructed, and, in the event of an affirmative decision, the commissioners were authorized to proceed to determine and establish the route or routes and the general plan of construction of such a railway.

(3) After they had determined upon the route and plans of construction the commissioners were instructed to submit them to the Common Council of the city for approval or rejection and the Common Council was in turn instructed to render its decision within four weeks of the date when the plans were submitted to them. In case the Common Council approved the plans the commissioners were instructed to secure next the consent of the property owners.

(4) Should the commissioners not be able to obtain the required consent of the property owners they were empowered "to make application to the general term of the Supreme Court in the judicial district in which such railway is to be constructed for the appointment of three commissioners to determine and report after due hearing whether such railway ought to be constructed and operated." This report was required to be made within 60 days after the appointment of the special commissioners.

(5) When the consents of the local authorities and the property owners, or in lieu thereof, the authorization of the Supreme Court, should have been obtained, the Board of Rapid Transit Railroad Commissioners was instructed to proceed to prepare detailed plans and specifications for the construction of the proposed rapid transit railway.

(6) After having prepared detailed plans and specifications the Board was instructed to sell at public auction "the right, privilege and franchise to construct and operate" the proposed railway.

The manner in which these various provisions were to be carried out was specified by the act in detail. It also contained a provision specifying in detail the manner in which the company or corporation, which was to construct and operate the railway, and "to enjoy and exercise the rights, privileges and franchises in this act provided," was to be created and organized.

On Dec. 23, 1890, Hon. Hugh J. Grant, then Mayor of New York city, appointed, under the first provision of the rapid transit act, the following Commissioners: William Steinway, John H. Starin, Samuel Spencer, Eugene L. Bushe and Frederick P. Olcott. Mr. Olcott resigned his appointment, and Mr. John H. Inman was appointed in his place. These Commissioners organized and began work within 30 days of the date of their appointment. Their first act was to invite suggestions as to routes, plans and manner of construction, and such suggestions were received in great numbers. Based upon these suggestions, and upon a "personal investigation as to the exact needs of the city in its several localities," the Commissioners adopted on May 27, 1891, a resolution from which the following is an extract:

This Board hereby approves of a plan for an underground four-track railway under Broadway from a point at or near South Ferry to 59th St.; thence under the Boulevard (now Broadway—Ed.) to a point at or near 169th St., with such length of viaduct at and near Manhattan St. as may be necessary; thence under Eleventh Ave., or under private property immediately to the west thereof as may be found most convenient, to such a point as the contour of the ground may determine; thence by viaduct across Spuyten Duyvil Creek and by tunnel or viaduct to the city limits.

On July 22, 1891, the Commissioners adopted a second resolution, from which the following is an extract:

This Board approves a plan for an underground four-track railway diverging from the proposed Broadway line at or near 14th St., thence under Union Square to Fourth Ave., and under Fourth and Park Aves. to near and south of 42d St.; thence by suitable curve to the westward under such private property and streets as shall be found practicable to Madison Ave. at or near 44th St.; thence under Madison Ave. to a point near 96th St.; thence curving to the eastward to a point not less than 100 ft. east of Madison Ave.; thence by viaduct over private property parallel to and not less than 100 ft. east of Madison Ave., to a point near and south of 134th St.; thence by curve to the eastward and by bridge across the Harlem River.

Immediately after the adoption of these resolutions the engineers of the Board, Mr. Wm. E. Worthen, M. Am. Soc. C. E., Chief Engineer; and Mr. Wm. Barclay Parsons, M. Am. Soc. C. E., Principal Assistant Engineer, were instructed to prepare two separate plans, one for four tracks on a single level, and the other for a double-deck tunnel, with two tracks upon each deck. On July 28, 1891, Mr. Worthen submitted plans for a line having four tracks on the same level, and on the same day Mr. Parsons submitted plans for a double-deck four-track line. These plans of the Board's engineers were then submitted separately to Mr. Octave Chanute, M. Am. Soc. C. E., of Chicago; Mr. Joseph M. Wilson, M. Am. Soc. C. E., of Philadelphia, Pa.; Mr. Theodore Cooper, M. Am. Soc. C. E., of New York city; and Mr. John Bogart, M. Am. Soc. C. E., then state engineer of New York, "with instructions that they were submitted not only for approval or disapproval, but for such general discussion and such suggestions as to alterations and additions, as might in their judgment be regarded as necessary or desirable to accomplish in the best manner possible the objects sought." Each of the consulting engineers submitted a written report accompanied by plans.*

Based upon the engineers' reports, and upon its own studies, the Board, on Oct. 20, 1891, adopted a route following the lines shown on the accompanying sketch map, **Fig. 1.** The construction proposed by the Board for these lines was as follows:

The general plan of construction of the loop under Battery Park, State and Whitehall Sts. shall be double track; from the Morris St. junction to near Vesey St. shall be three parallel tracks on the same level with suitable switches and connections between them; from Vesey St. to 119th St. on the west side line shall be four parallel tracks on the same level; and thence across the Government Ship Canal and Spuyten Duyvil Creek to the city limits shall be two parallel tracks on the same level. On the east side line from 14th St. to the Harlem River shall be four parallel tracks on the same level, and thence to the city limits shall be two parallel tracks on the same level. The tunnels shall be not less than 11 ft. 6 ins. in height in the clear, and 11 ft. in width for each track. Whenever necessary for the proper support of the surface of the street, the roof of the tunnel shall be of iron girders with solid plate iron covering supported by suitable iron columns between each of the tracks, and supporting walls on the outside. The roof of the tunnel shall be as near the surface of the street as the pipes and underground structures now laid therein and the street grades will permit. Viaducts shall be of masonry or iron, or both combined. The Government Ship Canal and the Harlem River shall be crossed by double track drawbridges not less than 50 ft. in the clear above mean high-water mark, with clear spans of not less than 125 ft. between the center piers and bulkhead line. North of the Harlem River the construction shall be by viaduct, depressed structure and tunnel as the grades of the land upon the proposed routes shall require. The junction of the tracks

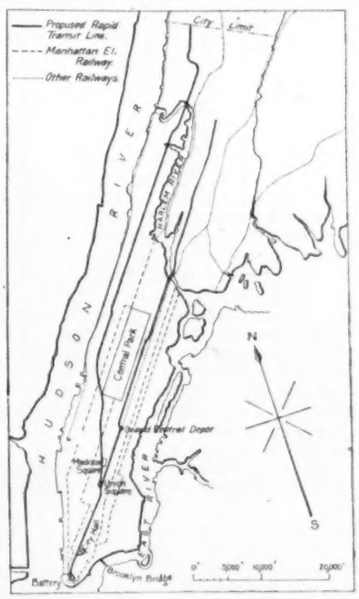


Fig. 1. Route for Rapid Transit Railway Adopted by the Rapid Transit Railroad Commission of 1891.

near 14th St. shall be effected by dividing them around Union Square, raising one pair and depressing the other, so that trains going in opposite directions shall not cross on the same level. All station approaches shall be as far as possible through private property to be acquired for that purpose, except that on the Boulevard, station approaches may be in the center of the street. A footway shall be provided the whole length of the line between the center tracks and refuge niches shall be built in the side walls at proper intervals for the convenience and protection of employees. The motive power shall be electricity, or some other power not requiring combustion within the tunnel; and the motor or motors shall be capable of a uniform speed for long distances of not less than 40 miles per hour, exclusive of stops.

On Oct. 21, 1891, the plans of the Board were submitted to the Board of Aldermen of the city of New York for approval, which was formally granted on Oct. 28, 1891. On the same date the approval and consent of the Department of Public Parks and Commissioner of Street Improvements were granted to the Commissioners. These formal actions by the municipal authorities cleared the way for the Board to secure the consent of the property-owners along the proposed routes, and here the first obstacle in the hitherto smooth course of the Board's progress was encountered. Strong objections were raised against the construction of both the Broadway line and the Madison Ave. line by the owners of the abutting property. It soon became evident that no

*The full reports of the commission's engineers and of the consulting engineers were published in Engineering News, 1891, Vol. II.; pp. 335, 346, 386, 390.

for several reasons to be remembered by engineers.

At the American Institute Fair held in New York city in 1867, Mr. Alfred Beach had on exhibition a circular wooden tube 107 ft. long and 6 ft. in diameter, back and forth through which a car seating ten persons was propelled by air pressure. The device was a large scale example of pneumatic dispatch, such as is now extensively employed, using small metal tubes, for transporting mail matter, telegrams and small parcels. The Beach Pneumatic Underground Railway Co., chartered in 1868, was an attempt on the part of Mr. Beach to establish his system of transportation on a practical scale for city passenger traffic, and he actually constructed some 200 ft. of 8-ft. tunnel from Warren St. north under Broadway. This tunnel still remains as the builder left it. It is more important to note, however, that Mr. Beach invented a shield, with which he constructed his tunnel, and, which was the first tunnel shield used in America. It may be worth while also to recall the fact that Beach's shield is the third device of its kind to be actually used in tunnel construction, it being antedated only by the first Thames Tunnel shield of Brunel and the London Tower Tunnel shield of Barlow and Greathead.

The short section of Beach's pneumatic railway was put in operation for exhibition in 1870. The

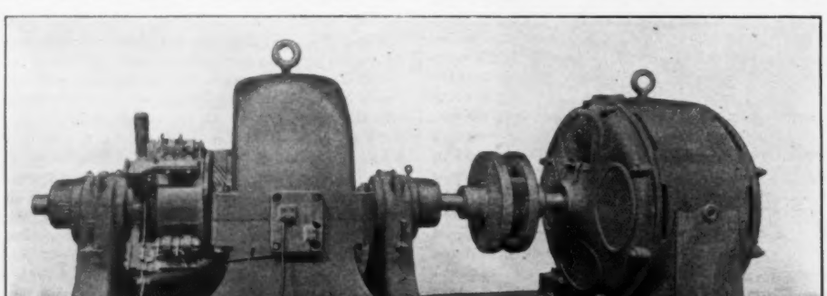


FIG. 4. MOTOR-GENERATOR SET IN SUBSTATION OF MANHATTAN RAILWAY CO.

year 1872 saw the inception of the last underground rapid transit railway project for New York city which was to be developed for nearly a score of years. This was the line of the New York City Rapid Transit Co., from Battery Park to 59th St., which was promoted chiefly by Mr. Cornelius Vanderbilt, as a downtown connection of the steam roads entering the Grand Central Station at 42d St. Meanwhile, however, the movement had begun which was finally to provide the city with a system of elevated railway remarkable throughout the world for its extent and for the amount of traffic handled.

THE DEVELOPMENT OF ELEVATED RAILWAYS.—The practical beginning of elevated railways in New York city dates from 1871, when the short line of the West Side (patented) elevated railway was purchased under foreclosure proceedings by the New York Elevated R. R. Co., which began its operation in 1872 from Battery Park along Greenwich St., and Ninth Ave. to 30th St. In that year also the Gilbert Elevated Ry. Co. was organized to build a railway along a portion of the route occupied by the present Sixth Ave. elevated line. In 1878 this company changed its name to the Metropolitan Elevated Ry. Co. The elevated railways of New York city, with one exception to be noted later, were built by these two companies, but before they had been completed the Manhattan Ry. Co. had been organized under the Rapid Transit Act of 1875, to lease the combined properties. This lease was executed on May 20, 1879.

As the Rapid Transit Act of 1875 calls for attention further on, it requires a brief explanation: At an early period in the work of elevated railway construction, it became evident that the New York Elevated and the Gilbert Elevated railways were not likely to work out a system of lines which would be at all an adequate solution of the existing transit problems, and accordingly an act was introduced in the State Legislature which provided for the appointment of a commission with full power to decide upon a general plan and devise means for carrying it out. This act became a law early in 1875, and in October of that year the Commission appointed under its authority made a report. This report recommended, in substance, that a double-track elevated railway be built on each side of the city, either by the two companies named above, which were already in the field, or else by another company provisionally organized under the powers conferred upon the Commission, and called the Manhattan Ry. Co. Without entering into details it may be again stated that the elevated railways were actually built by the original companies, but that after completion they were leased to the Manhattan Ry. Co. The physical development of the properties may be briefly described as follows:

The New York Elevated Ry. Co. extended its original Ninth Ave. line from 30th St. to 83d St., on the west side of the city, and on the east side it built the Third Ave. line from South Ferry to the Harlem River, with its branches in 34th St. and 42d St., and to the City Hall. The Metropolitan Elevated Ry. Co. completed its original Sixth Ave. line to 59th St., with a branch along 53d St. to Ninth Ave.; secured a half interest in the New York Elevated Ry. Co.'s line from 53d St. to 83d St., and constructed an extension from 83d St. to 155th St., all on the west side of the city. On the east side it built the Second Ave. line from Chatham Square to 129th St. The Second Ave. line was the last to be constructed and it was completed in 1880. In 1887 the line was extended across the Harlem River to a connection with the elevated line of the Suburban Rapid Transit Co., running to 177th St., and the Suburban Rapid Transit Co. was at the same time leased by the Manhattan Ry. Co.

The first official action looking toward the present underground rapid transit railway was taken in 1891. To summarize briefly, there were, in New York city, in 1890, two lines of elevated railway on the east side extending from South Ferry to the Harlem River, and there connecting with a single line to 177th St., and on the west side there were two lines from South Ferry to 53d St. and a single line from 53d St. to 155th St. Altogether, there were 36.19 miles of main line and branches, of which 36.19 miles were double track and 14.45 miles were three track. These lines in 1890 carried 190,024,848 passengers. Of surface railway there were 247 miles of track in New York city in 1890, of which eight lines of double track extended substantially the whole length of Manhattan Island. These surface roads carried 217,819,887 passengers in 1890.

With the completion of the elevated railway system in 1887, the first chapter in the history of rapid transit in New York city was practically concluded. It is doubtful if a more important chapter will ever be recorded. The present underground railway will be, in many respects, a marked improvement over the older elevated lines, but it will not be such a vast improvement over preceding methods of transit as were the elevated lines when they were constructed. Great praise is due, therefore, to the Rapid Transit Commission of 1875, whose work crystallized public opinion, formulated the plan, and reconciled the diverse financial interests which co-operated in producing the present elevated railway system of New York city.

THE RAPID TRANSIT COMMISSION OF 1891.—As has been shown, engineers set out with the notion that the rapid transit problem of New York city would be best solved by an underground railway. The voice of the people, however, favored elevated railways and they were built. For nearly 20 years, from 1872 to 1891, underground railway projects received scant consideration; the field was too completely dominated by the elevated lines. Meantime, however, the public had conceived a prejudice against elevated railways, and the popular clamor which had demanded this form of structure at the outset was now raised with tenfold strength against it and in advocacy of an underground railway. We need not at present concern ourselves with the reasons which lay behind this revulsion of feeling; some of them were logical ones and some were not. The point which it is of importance to emphasize here is that they made possible the beginnings of the movement which is now receiving actual structural embodiment in the rapid transit railway.

Between 1880 and 1890 a multitude of schemes were forthcoming by which their promoters hoped to satisfy both the real need for better rapid transit facilities and also the public feeling against the elevated roads. Of these only a few can be mentioned, and of those deserving mention the so-called Arcade Railway scheme is the first to merit attention. This scheme was proposed by the New York District Ry. Co., incorporated in 1885, and it involved the construction of a four-track underground railway from Bowling Green, up Broadway to Madison Square, where the four-track line was to fork into two double-track lines. One of the double-track lines was to continue up Broadway to Ninth Ave., and the other was to run under Madison Ave. to and across the Harlem River to Mott Haven. Electricity was to be the motive power, and the estimated cost was $3,000,000 per mile. Mr. Wm. Barclay Parsons was the engineer in charge.* There seemed at one time a fair prospect that this company would go ahead with actual construction, but its plans were brought to naught by a decision of the Court of Appeals holding unconstitutional the act under which the company expected to work.

Late in January, 1888, another notable announcement respecting rapid transit was set forth in the message of Mayor Abram S. Hewitt. This message outlined a comprehensive rapid transit railway system. Briefly summarized, the Mayor proposed that the line to be built should connect at 54th St. with the two local tracks of the New York Central & Hudson River R. R., coming from the Harlem, and from 54th St. should pass under the Grand Central Station and the Fourth Ave. tunnel to 32d St., thence along Fourth Ave. to Ninth St., along Ninth St. to Lafayette Place, under Lafayette Place and through a new street to the Elm St. improvement, and thence to City Hall. The whole line was to be in tunnel and open cutting, and was to have four tracks. Below City Hall surface tracks were to run down Broadway to the Battery, and be employed to bring people to the City Hall station of the main line. Several other subsidiary surface lines were also provided and alternate plans were suggested for the main line. Nothing ever came of this proposition, which was obviously open to several objections. In March, following Mayor Hewitt's message, the City Ry. Co. was incorporated to develop a system of rapid transit. This company set out with the somewhat novel proposition to

*A brief description and several illustrations of this proposed underground road were published in Engineering News of Jan. 2, 1886.

skew arches, and also ribbed arches. The transverse section in Fig. 3 shows the method of clamping the arch ribs together transversely of the arch. The contractor for the bridge is C. A. Sims, of Philadelphia, Pa. We are indebted to Mr. Wm. H. Brown, Chief Engineer of the Pennsylvania R. R. Co., for the information from which this description has been prepared.

CURRENT PRACTICE IN ELECTRIC RAILWAY CONSTRUCTION AND OPERATION.

An indication of the development of the electric interurban and cross-country railway as a work of engineering is afforded by the fact that this particular branch of engineering is beginning to

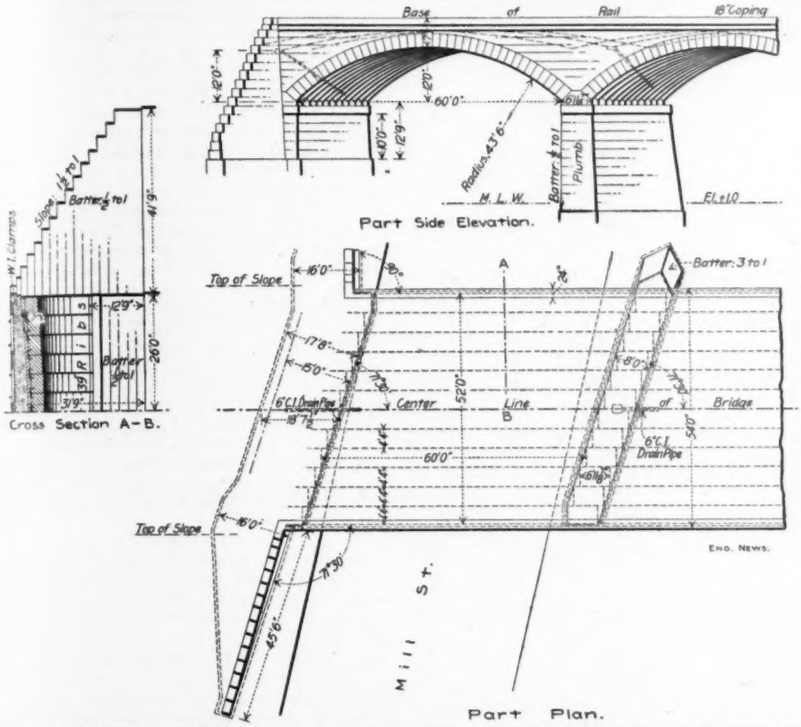


FIG. 3. GENERAL ELEVATION, PLAN AND SECTION OF SKEW ARCH, TRENTON BRIDGE, PENNSYLVANIA R. R.

be discussed at the meetings of engineering societies. At the recent annual meetings of the Illinois Society of Engineers and Surveyors, and the Michigan Engineering Society papers were presented dealing respectively with the construction and operation of electric railways, and abstracts of both these papers are given below. Two points to which special attention may be called in the first paper are: (1) The peculiarities of location governed by right-of-way considerations, the right-of-way being sometimes acquired before the location is made, and (2) The failure of the field-books and tables prepared for the use of the engineers of steam railways to fully meet the requirements of the engineers of electric railways:

LOCATION AND CONSTRUCTION OF AN INTERURBAN ELECTRIC RAILWAY.

By. C. C. Stowell, M. W. Soc. C. E.*

Those of us who are accustomed to locate railway lines for economical operation and minimum expense in maintenance, with the right-of-way adjusted to the work, will find it hard to reverse this order and locate the line to fit the right-of-way, making expense of operation and maintenance the secondary consideration. Probably the first feature that presents itself as peculiar in electric railway work will be that the right-of-way must be located before the center line of the track can definitely be determined. And if the ground is even ordinarily rough the center line must be curved and shifted in order that the slopes may not fall outside the right-of-way or the grades become excessive. The locating of the right-of-way, if conscientiously done, requires much time, and the careful running of many section lines. In this work, the lack of monuments is forcibly felt. An experienced locating engineer will take many a side glance at better ground, and deplore his cramped conditions.

*Rockford, Ill.

A second peculiar feature that is sure to appear is that the line, and in some instances the right-of-way, must be shifted to avoid shade trees. Houses or other buildings may be moved, but trees must not be disturbed. Where the line follows the side of a highway, the grade must be so adjusted as to leave all drives and gateways as nearly as possible in their original condition. The compensating of grades for curvature is usually disregarded. Indeed, the tables usually given in field books, to assist the engineer on location, are of little use in this work. The tables of 1° curves for chords of 100 ft. can be used occasionally, but for curves having a radius of 100 ft. and 200 ft. they are sadly deficient. At the present rate of increase in electric interurban projects, there will soon be a demand for a book of tables and formulas for this special work.

About the only feature that will seem natural to an engineer of railway experience in laying out an electric line is the care for the waterways. The grading, although light, is difficult and expensive, owing to the narrow right-of-way. The width of roadbed seems to be fixed at 12 ft., though it is strange, in the light of the experience on steam roads, that any less than 14 ft. should be thought of. After material has been taken from a bank of 12 ft. in width, with which to surface the track, the shoulders and a good portion of the slopes have disappeared. This material must be replaced from gravel trains at an early day, at much greater expense than the building of a 14-ft. bank in the first instance. The replaced slopes are by no means as permanent as when built with the main bank, and if not closely watched rains will endanger the track.

The Rockford & Belvidere Electric Ry. Co., with which I have been associated during the past season, put excellent material in the track, with the idea of occasionally giving trackage to locomotives and hauling freight cars from steam roads. Oak ties, 60-lb. rails, and Weber joint bars were used, with spring frogs and split switches in all turnouts. All bridges were built to carry freight cars of 50 tons capacity. Concrete arches and sewer pipe were used in small waterways, and steel and timber structures over the larger. The trolley wire was carried on span wires between poles in the usual manner. This gives flexibility to the system, which is a desirable feature, but owing to the limited space in which to place the poles, I am of the opinion that a bracket system, with the trolley wire held to the bracket by means of suitably arranged springs, would be preferable.

ELECTRIC RAILWAYS.

By W. J. Sherman.*

Sometimes we can but wonder if the innumerable transformations and attendant tremendous losses in power from the coal heap to the axle motor will not stimulate the wonderful inventive genius of the age to the production of a more economical power. The boiler losses average about 25%, generator losses average 2%, and the net available power in a well-built station should range from 4 to 4½%. Is not this showing enough to cause us to pause and wonder if some more economical adaptation of power is not in store for us in the early future?

*Riggs & Sherman, Civil Engineers, Nasby Building, Toledo, O.

It is not uncommon for an interurban railway 40 or 50 miles long, in the gently rolling country of the Middle West to cost $20,000 to $25,000 per mile, with only 40 or 50% chargeable to the railway proper. To the writer, such an investment (considering the inferior roadbeds being built in most instances) seems excessive, where passenger earnings comprise such a large percentage of the total earnings. It is a well-known fact that passenger earnings are not in themselves profitable to the steam railways save as they serve to stimulate the freight earnings, constituting as they do but about 20 to 25% of the total earnings, and this at an average of about 2½ cts. per mile for fare as against 1¼ cts. on the electric line.

Most of the interurban lines have been in operation sufficiently long to determine what net earnings can be depended on. Many of the interurban roads are still in their infancy. The cars and machinery are new, ties are still sound, and rails have not yet begun to show signs of wear. Repairs are slight and renewals have not begun to appear in the operating expenses. But a general depression will come. These good times cannot continue indefinitely, and the thoughtful manager must prepare himself for a struggle to pay his operating expenses and the fixed charges on the watered bonds, which are the usual product of periods of unusual prosperity.

Can anything be done to stimulate earnings and enable the road to tide over a period of depression? Yes, there is something which can be done by almost every interurban line in the country, that is develop the freight traffic. There is plenty of it and it is only awaiting proper facilities to be diverted from the wagon and steam roads, chiefly the former, to the electric roads. It is more profitable than the passenger business, and it is not a little surprising that it is receiving practically no attention on most of our interurban roads at the present time. But the roads are mostly new and the business is young and doubtless most of the managers will shortly be giving the subject the attention it deserves.

It is a well-demonstrated fact that those roads which are the best constructed and which are maintained in the most perfect condition physically are showing the largest percentage of net earnings on the investment, other things being equal. In other words, it pays to build well and maintain well, and high standards are profitable. A prominent electric railway engineer has stated to the writer that one of the well-known syndicates engaged in extensive railway construction had very recently decided that it could not hope to construct and fully equip in accordance with a correct standard for much less than $40,000 per mile in the Middle West. If this statement is true, it means a very much superior type of construction

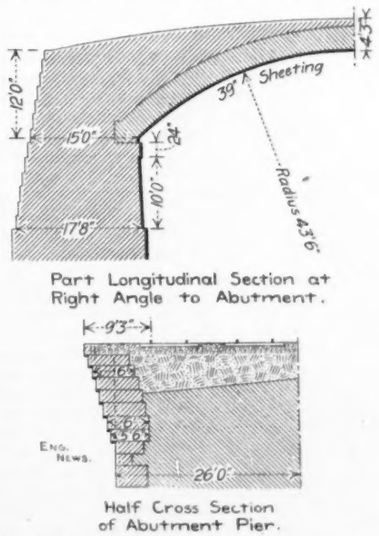


Fig. 4. Detail Sections at Abutment and Abutment Pier, Trenton Bridge.

to any we have seen yet, and emphasizes very emphatically the point the writer is trying to establish, viz., that the electric railways to-day are still in their transition period.

A TRAMWAY IN SHANGHAI, CHINA, is wanted by the ratepayers of the International Settlements. At a meeting recently held tenders were asked for, to be submitted to the next meeting; these tenders to be sent to the Council Office, Shanghai, before March 7, 1902. No information is given, other than that "explanatory pamphlets" can be seen at the Board of Trade, 50 Parliament St., London, England.

agreement with the hostile property-owners was to be arrived at, and early in 1892 the Board made application to the Supreme Court for the appointment of three special Commissioners to report upon the matter in dispute, according to the provision of the act stated in paragraph No. 4 of the summary of the act given above. These Commissioners were appointed and they submitted a report on June 17, 1892, which held, in substance, that there was public necessity for the whole west side line, and for that portion of the east side route between Broadway and 14th St. and the Grand Central Station at 42d St., omitting, however, the extension of the east side line up Madison Ave. and beyond. Upon confirmation of this report by the Court the Board of Rapid Transit Railroad Commissioners was in position to resume its labors, which it did at once.

In November the work of the Board had reached a point where it was possible to issue specifications and terms of sale for the franchise. According to the specifications issued the franchise was to be sold to the highest bidder at the New York City Hall on Dec. 29, 1892. The terms of the sale required 10% of the amount bid to be paid in cash and the remainder within 30 days. The successful bidder must deposit $1,000,000 cash with the City Comptroller, and file a $2,000,000 bond with the Mayor as security for the faithful performance of the contract. The successful bidder might form a company to build and operate the road, the capital stock of which should be $50,000,000, and it might issue bonds to the same amount. The plans, specifications, and terms of sale were objectionable and faulty in several particulars,* and when, on Dec. 29, the time for receiving bids for the franchise was due, no bona fide bid was submitted.

There now came a period in the work of the Commissioners to which those really interested in promoting rapid transit in New York city look back with scant pride. It is but just to note, however, that previous to the events which are now to be related, the whole engineering staff of the Commission, including Messrs. Worthen and Parsons, was abandoned, so that the original engineers had no responsibility whatever for these events. Subsequent to the retirement of the original staff a new one was organized in the spring of 1893, under Mr. John Bogart, M. Am. Soc. C. E., Chief Engineer. On Jan. 19, 1893, the Manhattan Ry. Co. applied to the Commissioners for power to lay a third track on all but a small portion of its elevated lines, and also for authority to build several extensions. On March 11, the Commissioners reported upon this application, the report granting certain of the privileges applied for and denying others, and also making several demands in the way of motive power, speed, rates of fare, etc. In May the Manhattan Ry. Co. submitted a letter to the Commissioners rejecting their plans. Internal dissensions now arose in the Board, and a month later all but one of the Commissioners resigned their offices. These resignations were withdrawn in less than two weeks, however, and the Board again resumed its dickering with the Manhattan Ry., to which it made a new offer of the franchise with modified terms. This offer was refused on the plea that "owing to the present disturbed financial condition of the country, it is deemed unwise to make any large contracts for extensions."

After this rebuff the Commissioners assumed what was aptly called a position of masterly inactivity. It was fully six months indeed before the public was granted the confidence of their deliberations, and then, early in December, 1893, it was made cognizant of the fact that the Board had "agreed" upon a west side elevated line, and had ordered its engineers to prepare a general plan of construction. A month later the public was again surprised by an announcement from the Board that bona fide bidders had offered to carry out a project originating with Mr. Eugene L. Bushe, one of its members, and involving a material extension of the elevated railway system of the city. Shortly afterward a bidder, Mr. R. T. Wilson, made an offer to build an underground railway on the route laid down by the Commissioners. The Bushe project was shelved, and the Wilson project was formally approved by the Commissioners early in February, 1894. A week later the Commissioners announced that the Wilson project had been "withdrawn" by its promoters, and that the consideration of the Bushe elevated railway project had been again resumed. Meanwhile, through the efforts of the New York Chamber of Commerce, an amended rapid transit act, providing for an entirely new Commission, had been started on its way through the State Legislature, and upon the passage of this act and its approval in May, 1894, by Governor Roswell P. Flower, the Board of Rapid Transit Railroad Commissioners of 1891 and its work came to an inglorious end.

*A full discussion of these objections was published in Engineering News of Nov. 24, 1894.

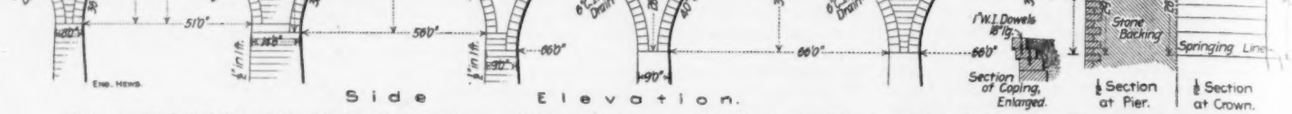


FIG. 1. ELEVATIONS AND SECTION OF 51-FT., 56-FT. AND 66-FT. ARCHES, NEW BRUNSWICK BRIDGE, PENNSYLVANIA R. R.

MASONRY ARCH BRIDGES AT TRENTON AND NEW BRUNSWICK, NEW JERSEY; PENNSYLVANIA R. R.

The accompanying illustrations show the details of two new stone arch bridges which are to be built during the present year by the Pennsylvania R. R. Co., in accordance with its well-known policy of replacing steel bridges, when the conditions are favorable, with masonry arch structures. One of the new bridges will cross the Raritan River at New Brunswick, N. J., and the other will cross the Delaware River, between Trenton and Morrisville, N. J. At both sites the foundation bed will be rock, generally, only a few feet below the water surface, and both structures will be entirely of stone masonry, the concrete backing used in the similar structure at Rockville, Pa., which has just been completed (Eng. News, May 10, 1900; Dec. 12, 1901), having been abandoned in the more recent designs. We are informed by the engineers that this change of material was not the result of any failure or trouble with the concrete backing used at Rockville, but was due to the general preference of Chief Engineer Wm. H. Brown, for stone where it is equally available. In size the two bridges illustrated will be inferior to the Rockville Bridge; but with this exception there are few if any masonry arch railway bridges in the United States which equal them in the general dimensions.

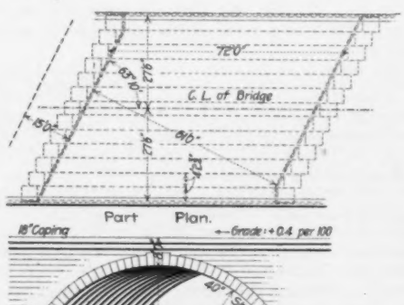


Fig. 2. Elevation and Plan of 72-ft. Skew Arch, New Brunswick Bridge.

NEW BRUNSWICK BRIDGE.—The new stone arch bridge across the Raritan River at New Brunswick, N. J., will be a double-track structure consisting of 21 spans, of which eleven will be 66 ft., one 56 ft., eight 51 ft., and one 72 ft. in the clear. It will replace a steel bridge carried on masonry piers, which for the portion of the new bridge crossing the river proper will be cut down and used again, but which will be removed entirely and replaced by new piers on the shore portion of the structure. Altogether five of the old piers will be reused, and four will be removed, together with two abutment arches on the east shore. The piers which will be reused are spaced about 132 ft. apart, so that a new pier is required between each pair to carry the 66-ft. arches. The piers for the new structure will be 9 ft. thick at the springing lines for the 66-ft. arches and 8 ft. thick for the 51-ft. arches. At the shore end of the 56-ft. span a 14-ft. pier is introduced, and at the river end of the 72-ft. skew arch (Fig. 2) a wedge-shaped pier, about 38 ft. thick at one end and 10 ft. thick at the other end, is required, to separate the 72-ft. skew span and the adjacent 51-ft. straight arch. All piers have a rough-faced ashlar facing with a random backing, as shown by the half-transverse section in Fig. 1, and all are founded on the solid rock of the river bed.

The 20 straight arches of 66, 56, and 51-ft. spans differ only in their dimensions. The main dimensions are shown by the elevations in Fig. 1, which, in connection with the sections, show the profile of the masonry backing, the arrangement of the coping, and various other general details. The ring stones are to be laid with 1¼-in. mortar joints. The spandrel walls are of rough-faced ashlar laid in 22-in. courses. The 72-ft. skew arch, shown by Fig. 2, is composed of 13 ribs, each 4 ft. 2¾ ins. wide, which are fastened together at seven points along the extrados by means of wrought-iron U-clamps. The main dimensions of this arch are shown by the drawing, Fig. 2. The contractor for the New Brunswick Bridge is H. S. Kerbaugh, Inc., of Philadelphia, Pa. Work is now in progress by the railway company preparatory to removing the present steel structure to new temporary piers so as to leave the site clear for the new arch work.

TRENTON BRIDGE.—The new Trenton Bridge will be a stone arch structure, consisting of 18 skew arches of 60-ft. span in the clear. These arches will be carried on 15 piers 8 ft. thick at the spring lines, and two abutment piers 22 ft. thick at the springing lines. The abutment piers divide the bridge into three sections of six arches each. They differ from the main piers only in their dimensions, and in having a longitudinal extension of the coping at the downstream end to serve as a refuge for workmen. All piers are founded on rock and have an ashlar facing backed with second-class masonry. The location of the new bridge will be on a cut-off, which will eliminate the curve to the north which the main line now makes through Trenton and Morrisville. No portion of the present line or of the present bridge will, therefore, be disturbed in building the new bridge.

The details of the arch construction of the Trenton Bridge are shown by Figs. 3 and 4, and the work, therefore, calls for only a few general comments. It will be noted that all of the arches are

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The new Mayor of New York city was recently subjected to public criticism for not enforcing to its letter the law forbidding the sale of liquors on Sunday. In an exceedingly able reply to his critic, the Mayor pointed out that the responsibility with which he is charged is not to enforce obedience to this particular law alone, but to all the laws on the statute book; and that to devote undue energy to the enforcement of one particular statute to the neglect of others, would be disastrous to the public welfare and to every principle of good government.

It appears to us that an instructive parallel may well be drawn at this time between the position of the Mayor and his associates and the management of the New York Central R.R. The public just now is subjecting this management to the severest criticism for the condition of the Park Ave. tunnel, and demanding—usually with far more zeal than knowledge—the installation of all sorts of "improvements" possible and impossible. But will it not be conducive to a fairer judgment of the case if we stop and reflect that Mr. Newman and Mr. Wilgus and their associates have to carry the responsibility not only for the safety of that particular two-mile tunnel, but for two thousand miles or more of railway lines?

The public has its mind fixed just now on that two-mile tunnel as if it were the only existing point of danger on the entire system. Certainly, in view of our past utterances, we shall not be suspected of underrating the dangers of the tunnel; and yet the actual results of operation are that in nearly thirty years only three accidents have been recorded in that tunnel, resulting in the deaths of about 45 passengers. In the year 1900, alone, on the whole New York Central system, 350 persons (passengers, employees and others) were killed, and 609 were injured. We do not say this to belittle the dangers of the tunnel. Perhaps, considering the volume of traffic through it, it deserves attention now more than any other part of the entire system; but it ought to be borne in mind that it is, after all, only one of the thousand dangers which beset railway passengers and employees against which the officers of the company have to guard. If this obvious fact is kept in mind, one can judge more justly as to the measure of personal responsibility for the accident to which the railway company's officers should be held.

Again, there is a current fallacy afloat to the effect that the tunnel should be improved with absolute disregard of expense. The public cries out for the adoption of electric motive power in the tunnel with the blind idea that it is a sort of panacea for all ills.. Any suggestion that expense should be considered in connection with such a change is rejected with scorn. And yet the fact is, no matter how little the public may consider it just now, that expense ought to be fairly considered in any question of this sort; and it is against the public interest to ignore it.

If the company is to spend, say, fifteen million dollars to increase the safety of its traffic, it ought to distribute it, manifestly, to the points where danger is greatest. In other words, it should apportion the expenditure in such a manner that the total of human lives and limbs saved may be as large as possible. To concentrate the entire expenditure at one single point—to exhaust every resource of science and engineering on that one spot and leave every other place in its present state, is against the interest of the public, no matter how little that public may just now realize it.

Let us put the matter in a concrete form: The New York Central Company is likely to spend not less than fifteen million dollars in introducing a system of electric motive power to haul its trains through the Park Ave. tunnel. Practically the sole benefit to be derived from this system will be the avoidance of the discharge of smoke and gas in the tunnel, with the result that engineers can clearly see the signals, and that passengers and residents on Park Ave. will be relieved of annoyance. The other benefits in the way of increased traffic accommodations might be attained in other ways at far less expense, and will be fully offset, moreover, by the delay, annoyance and danger due to the change to steam locomotives at some point above the Harlem River.

Now suppose, instead of spending this huge sum at this one point, that a much smaller sum, say half-a-million dollars, for example, were spent to install a ventilation plant at the tunnel, sufficient to entirely clear the tunnel of smoke and steam in the interval between the passage of trains. Would not such a result satisfy every reasonable requirement of safety at this point? If so, then it is evident that the remainder of the sum which it is now proposed to spend on electric traction could be used to secure additional safety at other points. Are there not opportunities for such expenditure? How about the eighty grade crossings of city streets on the company's lines? On how many miles of the line are trains still operated without the protection of the block system? Are there not other improvements that might be introduced at a multitude of points on the line to conduce to safety?

We point out these plain facts in the interest of the public, and with little idea that the present tide toward electric traction can be stemmed. Most unfortunately for the company, its officers have taken the position that ventilation of the tunnel in any manner is impracticable; and the public, therefore, demands electric traction as the only remedy it knows of for the conditions in the tunnel. The company has yielded to the pressure of public opinion so far as to announce the adoption of electricity for the side tunnels; but it still desires to operate the central double-track tunnel with steam locomotives. But the recent accident which has so aroused the public occurred in the central tunnel, not in the side tunnels. There is absolutely nothing in anything the company has thus far announced concerning its proposed constructive changes which will prevent other accidents occurring in the future from the same cause as the accident of Jan. 8.

In view of this fact, the company has two alternatives. It can reverse its attitude toward ventilation systems for the tunnel and try to convince the public and the railroad commission that it can by such a system produce satisfactory results. If it does not do this, and adhere to its present position regarding the impracticability of fan ventilation, the probabilities are strong that it will be compelled by law to entirely abandon the use of locomotives on all trains running through the tunnel.

As an example of an absurdly short-sighted policy in the selection of railway gages, the present snarl in the five political divisions of Southern Australia is perhaps unapproached. Queensland originally selected a 3-ft. 6-in. gage; New South Wales, 4-ft. 8½-in.; Victoria, 5-ft. 3-in.; and Western Australia built upon a 3-ft. 6-in. gage. It is now proposed to connect these railways into one system—as might have been foreseen by their projectors, and the gage adopted for the connecting link is 4 ft. 8½ ins. As a consequence, a passenger starting at the western terminal of this 3,530 miles of railway will have to use five distinct trains to reach the eastern end; and freight must be likewise transferred four times in going over the same route. Experience here—as elsewhere, has at last shown the Australians that any gage over 4 ft. 8½ ins. entails unnecessary expenditure without compensating advantages; and good results, with any heavy traffic, cannot be secured on a 3-ft. 6-in. line; hence the late adoption of the 4-ft. 8½-in. gage for the projected connecting link. The greater system is supposed to tend to the industrial growth of Australasia; but the inevitable outcome of any such increase in traffic will be the compulsory unification of gages, with all the expenditure that this entails. It is another case of building for to-day without regard for the morrow.

The New York underground rapid transit railway is now under construction for a length of 21 miles on Manhattan Island. At present about one-fourth of the work has been completed, and the monthly payments to the contractors aggregate $1,000,000. By the summer of 1903, most of the line will be ready for operation. The cost of this railway makes it one of the most expensive municipal enterprises ever undertaken, and the amount of work to be done and the rapidity with which it is being prosecuted makes it rank high among engineering accomplishments. In round figures, the 21 miles of railway now under construction will cost $35,000,000. The work of construction involves the excavation of nearly 3,000,000 cu. yds. of earth and rock, and the placing in this excavation in structural form some 73,000 tons of iron and steelwork and over 500,000 cu. yds. of masonry. To operate this 21 miles of four-track and two-track railway there will be required electric power plants, the line and motor equipment, and the rolling stock, necessary to operate on separate tracks, local trains of three cars at two-minute intervals, and express trains of four cars at five-minute intervals. To engineers these figures indicate adequately the immensity of the work in hand, but they represent nothing of its variety and the methods and machinery employed to accomplish it, or of its difficulties and their solutions. These essential facts can be obtained only by a careful study of the work in person, and opportunities for such an investigation are possible to very few members of the engineering profession. It is to supply those who do not have these opportunities that we begin in this issue of Engineering News a series of illustrated articles outlining the history of the Rapid Transit Railway, and describing the machinery used and methods of work adopted in its construction. A full prospectus of these forthcoming articles is impossible at present, but their general character and scope can be indicated. The first two articles will be purely historical, and will trace the growth of the enterprise up to the time of awarding the contract for construction in January, 1900. The third article will describe briefly the work to be done and the organization which

has been devised for carrying it on. Succeeding articles will present the plans and specifications in detail, and describe the important work of sewer diversion. Following these, the machinery used and methods of work adopted on each of the 17 contract sections will be described. The concluding articles will relate to the projected tunnel extension to Brooklyn, to the power plants, line construction and car and motor equipment, and to the station construction. The several articles will be fully illustrated by drawings and views from photographs of the work in progress, and so far as the demand on our space will permit, an article will appear in every issue of the paper until the series is completed. With this brief outline of their plan and scope, we refer our readers to the first article of the series, which appears on another page of this issue.

The following note, clipped from our London contemporary, "The Electrician," may afford some amusement to American engineers:

> English electrical engineers have been often accused—and often unjustly accused—of slavishly following American practice, and of preferring to adopt ideas transmitted from across the sea to providing and perfecting their own. It is comforting, therefore, when this process is absolutely reversed, and that our best engineering methods are occasionally adopted as novelties in the United States after they have been subjected to long trial and become stereotyped in this country. One of the latest instances of this is the decision of the Pennsylvania Railway Co. to extend its railway into New York by a series of deep-level tunnels on the "tube" system.

Our contemporary is evidently laboring under the impression that the hydraulic shield system of tunneling with cast-iron tunnel lining has never been used in the United States. The fact is, of course, that the system has been extensively used here for many years, and is just as well recognized here as a standard method of engineering construction as it is abroad.

IMPROVEMENTS IN CAR COUPLERS AND DRAFT RIGGING.

The M. C. B. type of automatic car coupler may now be considered permanently established as the universal standard type of coupler for both freight and passenger equipment on American railways, and demands for a reconsideration of the coupler question with a view to the adoption of some different and better type are now growing fewer and fewer. Such demands or suggestions as are made receive but little attention, and rightly so, for while the M. C. B. type is not perfect, no other type has received so much consideration or care in its design, or has had such extensive practical service. Besides this, no other type has presented, even on paper, such advantages as would warrant the entire reopening of the coupler problem, and in fact it would be practically impossible to do this now that the adoption of the M. C. B. coupler has gone so far. These remarks may seem superfluous at this time, but different phases of the coupler question have recently come up for consideration at meetings of technical associations, and in some of the discussions the M. C. B. type of coupler has met with rather severe criticism, while statements have been made on the basis of what might have been and how much better a coupler might now be available if this type had not been adopted.

But while the M. C. B. coupler may now be said to be in universal service in this country, and to be giving (on the whole) practical satisfaction under the severe conditions of actual service, it is undoubtedly capable of further improvement in its details. Attention still continues to be given, therefore, to the design of the coupler and its attachments by inventors, manufacturers and railway officers; the Master Car Builders' Association is carrying out, through its committees, investigations with different styles of draft rigging; while the Western Railway Club, as the result of a lengthy discussion, has recently appointed a committee to review the whole subject of car couplers and draft rigging. The suggested improvements which are put forward from time to time cover practically every part of the draft equipment. It seems to be almost universally recognized in railway circles, however, that while general improvements in draft rigging are well worth consideration, and while the present form of coupler is capable of improvement in its details, yet a matter of far greater and more immediate importance is that of maintaining existing couplers in proper operating condition, and of securing greater uniformity in their parts.

Advocates of important changes in the M. C. B. coupler very generally enlarge upon certain individual difficulties or troubles, and give these undue preponderance in relation to the coupler as a whole. They forget, or fail to consider, the fact that thousands of couplers of this type are giving satisfactory results in regular daily service, and that the difficulties incident to their use are due largely to lack of uniformity, minor defects in design and construction, and to the lack of perfection which attends all human inventions. Troubles with making couplings between cars, when considered in comparison with the general and successful use of this particular type of coupler, appear to be very limited, existing only under certain conditions, and by no means demanding any radical or expensive change either in the coupler itself or in the draft rigging. One of the speakers in the discussion before the Western Railway Club, which is noted elsewhere, stated the case very clearly when he remarked that the present type of coupler was by far the most practicable one he had ever seen, and that its weak points are in the details rather than in the principles involved.

One particular feature of the coupler question, which has recently been brought up before two of three railway clubs, and which is discussed in another column, is the claim that greater flexibility of the couplers is necessary or advisable for three reasons: First, to enable cars to be coupled on sharp curves; second, in order to make the cars in trains pass more easily around sharp curves; and, third, to reduce the side pressure with which the wheel flanges bear against the rail heads on such curves. Two methods of effecting this flexibility have been suggested, and both have been worked out in various ways. In the first method, the coupler head is pivoted to the drawbar, so that it has a sort of horizontal knuckle movement. In the second method, the drawbar is pivoted in some way at its rear end, and is given increased lateral play in the yoke or carry-iron. The former of these methods appear to have been introduced mainly in passenger car and tender couplers, while the latter has been more generally applied in freight service. Neither, however, is in very extensive use. Opinion is, of course, divided as to whether such increase in flexibility is really worth what it costs to secure it, and those who advocate it are divided in opinion as to the proper means of effecting it. In this connection it is well to note the remarks quoted in another column in regard to the satisfactory performance of the present M. C. B. coupler in regular service, and in regard to the fact that too much lateral play or flexibility may be rather detrimental than beneficial.

It is evident from some of the remarks made in recent discussions that the difficulties experienced in the couplers on curves are largely incident to couplings between tenders and cars (especially long passenger cars). The tenders very generally have no drawbar, but an M. C. B. coupler head pivoted in a casting bolted to the end sill. The trouble, therefore, is due to a special condition, and can best be met by changes on the comparatively few tenders instead of by a general change in the coupler equipment of all cars. Serious troubles arising from difficulty in coupling cars on curves appear to occur but rarely, even in yards, and hardly seem to warrant, in themselves alone, any great or expensive change in the coupler arrangements. The point most worthy of consideration, probably, is that of the pressure of wheel flanges against the inner rails in passing round very sharp curves, due to the side pull of the couplers, but here the centrifugal force of the car tends to counteract this inward pull by throwing the car away from the inner rail, as explained in our issue of July 18, 1901.

A statement which has been put forward several times is to the effect that couplers are made too strong, thus encouraging rough handling of the cars in switching, by which draft timbers and their attachments, sills, and other parts of the cars, are made to suffer, although the couplers remain unbroken. This position does not seem to be well taken, especially as much of the damage complained of is undoubtedly due to the increased weight of large modern cars, which, of course, give more powerful blows, even when switched at the same speed as older and lighter cars. It is also to be remembered that many of the heavy cars are equipped with draft rigging which is not essentially stronger than that of the older and lighter cars. Under these circumstances, therefore, damage to the cars is not necessarily an indication that the cars are handled too fast or with too little care in the yards. Instead of making futile complaints or attempting to regulate the switching movements, it would be more to the point to make the sills, framing, and other parts which develop weakness, stronger than the couplers and draft rigging, and of proper strength for present conditions of working with heavy cars and heavy locomotives. There is no chance of reducing the size and weight of engines or cars, and it would certainly seem to be more reasonable to strengthen the parts of the car framing which fail in service of this kind, than to weaken the coupler for the purpose of making it the weak part which will fail first. This is particularly the case since the weights of cars and engines seem now to have reached their maximum. Of course, this strengthening of the draft attachments and the use of heavier draft rigging means an increase in cost, but not out of proportion to the cost of the modern heavy car itself, exclusive of the draft rigging.

It may be appropriate to mention here a device which is now being tried for taking up the slack between the couplers. This consists of a ring of manganese steel or hardened malleable iron fitted in the link slot of the knuckle and turning loosely on a pin 1 9-16 ins. diameter, which fits loosely in the pin hole of the knuckle. This ring may be circular or octagonal on its outer face; it is 3¼ ins. diameter and 2 ins. high, with the edges beveled so that they will not catch during any vertical movement of the couplers. As the diameter is 1/8-in. greater than that of the end of the knuckle, the two together will take up ¼-in. slack with new and unworn couplers, and a greater amount if applied to worn couplers. This device is the invention of Mr. W. F. Gould, of Des Moines, Ia., and is being tried on two engines and local passenger trains of the Chicago, Rock Island & Pacific Ry. The inventor states that the rings now in service have already been run 10,500 miles on the engines, and 9,000 miles on one of the cars; also that while the knuckles on the engine and cars were formerly renewed after about 5,000 miles, those now in use with the rings have already made 14,000 miles. Besides this, the shocks and jarring of the cars are said to have been greatly reduced, which is a particular advantage for passenger and stock trains.

The adoption of a uniform coupler, including a uniform knuckle and all other working parts, has several times been suggested, as a remedy for the present state of affairs, under which some makes of couplers fail to couple properly with those of other makes, although both nominally conform to the M. C. B. standards and requirements. This matter has been referred to in our columns at various times, and was discussed in our issues of Nov. 10, 1898, and June 25, 1900. In a recent discussion before the Western Railway Club it was again suggested that the advantages possessed by certain individual couplers should be combined in one uniform coupler for universal use, while at the same time further improvements in detail could be made; shanks strengthened, knuckle lug shortened and increased in section, lock and unlocking gear improved, link slot in knuckle dispensed with, etc. This matter is well worth consideration, and while it is quite improbable that one universal make of coupler could at present be agreed upon or adopted by all manufacturers and railway officers, yet the open discussion might lead to improvements in detail, and to a much-needed increase in the uniformity and interchangeability of couplers of different makes.

Troubles due to improper conditions of the couplers as maintained in service are by far the most important point in the whole question at

the present time. These troubles and difficulties form a really serious feature in the operation of traffic, and they cannot be provided against by any change in the form of the coupler or its attachments. The troubles are due in part to defective maintenance of the couplers, and in part to defects in manufacture; standards not properly followed, parts made too weak, knuckles of such form that they will not intercouple properly with those of other makes, lack of uniformity in uncoupling attachments, etc., etc. In either case, whether the defects are in manufacture or in maintenance, the responsibility and the remedy lie with the railways. They can (and should) strictly inspect new couplers, rejecting those which fail to meet the M. C. B. standards and the requirements of actual service; they also can (and should) see that coupler equipment is maintained in condition for proper and safe operation automatically and by hand. The present defective condition of large numbers of couplers has been presented again and again before the railway clubs and associations, but it would appear that measures to check or remedy the conditions have not yet been taken as generally or enforced as thoroughly as they should be. We have already shown that it is a very serious matter, and in this connection, and in conclusion, we quote the following remarks made in a discussion on the coupler question at a meeting of the St. Louis Railway Club:

Mr. George Hannauer (Gen'l Yardmaster, Terminal R. R. Association): I might say a few words from a switchman's standpoint. We have the greatest trouble with couplers, not from our inability to couple with them or anything of that kind, but rather from the defects that we find in them; defects which are perhaps the result of a lack of good care. It looks to the switchman as though the couplers were not getting the attention that they ought to have. If a train breaks in two because of the couplers, you generally find a defect there; either the knuckle is worn or partly broken, or the shaft is chipped, or there is some other defect in the coupler and it is generally a matter of wear or bad condition that causes the break. The chain on the coupler often breaks or there is too much slack in it, making it impossible to uncouple by the lever, causing a great deal of trouble in cutting off cars, resulting in the loss of time and personal injuries. In such a case the switchmen should stop the train, but in their diligence they do not like to do this; so they go in between the moving cars, or stand on the brakebeam and lift the pin with their fingers. I have known several serious injuries to occur in that way. I am told that in the yards of certain railways at East St. Louis, while a train of cars is standing for inspection under protection of the usual blue flags, a man from the repair track brings his small tools and such articles as can be applied while the cars are standing there, in order to make repairs on the couplers. That ought to do away with a great deal of the trouble if generally practiced. We find that about 20% of the cars will not cut by the lever. If we had in general use a simple arrangement (used on a great many cars) which is an uncoupling rod on each side of each end of the car, if the lever will not make the cut on the one car, the switchman could without changing his position reach the lever on the next car and make the separation. The chances of getting two bad ends together would be very slight; it would cost but a trifle, the switchman would take no chance of injury and save much time in doing his work. It is a simple thing and I am surprised that it is not used more.

Mr. Edw. Dunlop (Supt., Term. R. R. Ass'n.): I have in my observation concluded that the principal trouble in breaking drawbars and wearing out knuckles came from a tightness, or lack of space on the carry-iron in which the drawbar should move sideways in order to adopt itself to the curve properly. Our engines are equipped with a drawbar which hangs on a swivel, and we find they couple freely on any sort of curve. We handle the longest cars that are moved, upward of 80 ft. long, and so far have had no trouble with them. We have, as Mr. Hannauer has stated, great trouble with the automatic couplers by reason of their not being properly maintained. Chains and light levers became broken through lack of attention of the car department, but as a whole, I think the M. C. B. coupler is a good and suitable device, provided it is taken care of properly, and a space left on the carry-iron for the bar to move laterally.

LETTERS TO THE EDITOR.

Concerning Angle-Bar Sections.

Sir: Noting the letter of Mr. E. F. Wendt in your issue of Jan. 23, regarding defective angle-bar section, the writer does not see that there is any serious defect in the shape of the angle-bar section. The failure was caused, in the writer's opinion, by the metal in the angle bar being too soft, allowing the rail head to cut into it.

This defect, very often found in angle bars of late, has caused many engineers to favor a higher carbon steel for rail joints. Yours truly, L. L. Tallyn.

Champaign, Ill., Jan. 24, 1902.

Pouring on Grout is a Poor Way to Make Concrete.

Sir: A paving contractor sends me the following extracts from specifications on which bids for a considerable amount of concrete sidewalk and curb were recently asked by a town in an adjoining state, the contractor being required to comply strictly and yet to guarantee the work under bond. They may interest your readers, as an example of how unpardonable ignorance is sometimes condoned in "engineers" by trustful clients.

CURBING.—The curbing shall be 6×18 ins., of concrete or hard, durable stone. It shall be built true and plumb, lined to curb line as indicated by the stakes and conforming truly to established grade. If of concrete, it shall conform in construction and finish to the above specifications for the paving, but shall not be checked in squares; only cut in regular lengths to facilitate setting. If of stone, it shall be well set as above indicated. No bumps nor protuberances of over ½-in. will be accepted. Neither high nor low joints will be allowed.

PAVING.—The bottom course or layer shall consist of 3 ins. of gravel or cinders, well rammed, to be 3 ins. thick after ramming, and dressed smooth before concrete is put on. Where gravel is used, it must be clean and free from clay, soil or foreign substances. The rammer used must be of size and weight as set forth above. The second layer shall consist of 3 ins. of coarse gravel or broken stone, deposited smoothly and evenly. Where broken stone is used, the stones must not exceed 1½ ins. in size in any direction. This course of gravel or stone to be well grouted with thick cement grout until flooded, then rammed smooth until the moisture rises to the top. This course must be 3 ins. in thickness after ramming. The whole to be finished with a face of ½-in. of Portland cement mortar.

CEMENT.—For the second or concrete course, the best grade of Louisville or other natural cement of the same class and standard make may be used. For the face course, the best Portland cement must be used, etc.

Respectfully yours, Walter G. Kirkpatrick.

Jackson, Miss., Jan. 1, 1902.

End Area vs. Prismoidal Formulas.

Sir: The communication from Mr. B. W. Hicks, entitled "A Peculiar Prismoidal Section," in your issue of Jan. 9, leads to two conclusions which are a little surprising. First, for ordinary railroad embankment the method of average end areas gives results in error as much as 60%. Second, the prismoidal formula gives results in excess of the average end area method.

If, instead of attempting to find the volume of the prismoid given by averaging the top and bottom areas, the usual method of taking sections normal to the center line of the roadbed had been followed, we should have two wedges and a prism whose combined volume, by the average end area method, is 4,850 cu. yds., being in excess of the volume by the prismoidal formula which is as it should be.

Now, it is well known that for sections whose equivalent center heights vary more than about 5 ft., the average end area method gives results considerably in excess of those given by the prismoidal formula. Also, that the depth of a wedge should not be more than two or three feet. If we divide the 30-ft. deep wedges into a number of short prismoids, the first section, 3 ft. from the zero end, and the succeeding ones at intervals of 6 ft., giving 2 ft. for the depth of the first section and the others increasing by 4 ft., we shall obtain as the volume, by average end areas, 4,013 cu. yds., which is in excess of the volume by prismoidal formula less than ½ of 1%. It is probably true that the easiest way to compute the volume of prismoids of the shape illustrated is by the prismoidal formula; but it is also perfectly feasible to obtain comparable results by average end areas.

Yours truly, Geo. H. Tinker, Asst. Engr. C. & W. Ry.

Madrid, Colo., Jan. 17, 1902.

Reasons Why Cast-Iron Pipe Should Be Cast Hub End Down.

Sir: In the report in Engineering News of Jan. 16, 1902, (p. 18 of Supplement), of the discussion of the Standard Specifications for Cast-Iron Pipe at the January meeting of the New England Water-Works Association, there is an error of one word. That would seem to be a small matter, but it really made a change in the opinion I expressed in regard to foundry practice, to exactly the opposite. The controversy over the method of casting pipe hub end up, as compared with hub end down would, perhaps, be called by the pipe selling agents a small matter anyway, but my experience of two years as inspector at six different foundries, led me to commend the item of the specifications that required that the pipe should be cast hub end down and attempt to give good reasons why it should be insisted upon in all cases, as is shown by the following quotation from my written discussion of the report in question:

There has been a great deal said as to which end of the straight pipe should be cast down. An examination of the scrap heap at a pipe foundry will show that this is one of the most important items of the specifications. The carbon, silicon, etc., which are a part of all cast iron, are of less specific gravity than the iron itself. When the cast iron is in a fluid state, these lighter parts are constantly rising toward the surface. When the spigot end is cast up, the runners cover the upper surface so well that the lighter matter readily rises into the casting head, leaving the pipe itself in good condition. With the hub end cast up, the runners cover but a small part of the end of the hub, and the bottom of the socket thus provides a lodging place for the cinder. The hub of the pipe, cast with that end up, will, when broken, show in almost every case holes and collections of cinder. When subjected to the proof of 300 lbs. per sq. in., hydrostatic pressure, leaks will frequently show at once, but in many cases the water will begin to come through only after the pipe has been under the pressure two or three minutes. Upon examination it is often found that the passage of the water is several inches in length from the point of entrance to the outlet. All makers cast the large sizes of pipe, hub end down, and some cast all sizes that way. A pipe maker who has the facilities for doing the work both ways will, if he has had experience with inspectors, usually prefer to make the pipe hub end down for rigid inspection, for he knows that there will then be few rejections.

Yours truly, Geo. E. Manning.

New London, Conn., Jan. 20, 1902.

The Relative Merits of the Swing and the Bascule Types of Drawbridge for Wide Channels.

Sir: At Saginaw, Mich., there is much discussion about the erection of a new bridge across the Saginaw River on Genesee Ave., the principal thoroughfare through the central part of the city, adapted to street car and miscellaneous traffic. The present bridge was designed and constructed in 1886 by the Smith Bridge Co. (now Toledo Bridge Co.), of Toledo, O. It is about 20 ft. wide between trusses, with a footwalk 5 ft. wide outside of each truss; 196-ft. swing span, with about 70-ft. clear openings for the passage of vessels, and designed to carry a live load of 80 lbs. per sq. ft. Two lines of track for street cars (light horse cars were in use) were laid on this bridge, and everything worked smoothly for four or five years until the heavy electric cars were brought into use, and these were too heavy for the floor system.

A new bridge was proposed and the city engineer got up a design including a Scherzer rolling-lift draw span. The clear waterway was to be 90 ft., making each arm of the lift about 55 ft. long; width over all, 60 ft. But "there is a place for everything in this world, and everything has its place." The Saginaw River is a navigable stream 600 to 700 ft. wide; the grade of the present bridge is 15½ ft. above low water and only 7 ft. above high-water line. There is a paved street less than 200 ft. from end of draw span at and near the high-water line, which cannot be elevated so as to raise the floor of the bridge. Consequently the working parts on the abutment will annually be from 5 to 7 ft. under water. Then again, on a navigable stream where there is ample width for a pivot pier and swing span with two openings for navigation, is it not better to use the swing type of bridge, and keep the grade down to 14 ft.? In a narrow stream or canal where there is not sufficient width for the pivot pier, the lift bridge is a necessity; there it has its place, and is coming into general use. If the level of the Saginaw bridge could be raised 10 or 15 ft., the lift type of draw might be used to good advantage, and the rest of the bridge might consist of a series of flat arches composed of concrete and steel beams, making a very handsome structure. The city has sent a committee to Chicago to inspect the various lift bridges, some of whom favor the Scherzer lift, and others oppose it, because the working parts would come 7 ft. below the high-water line. Some good bridge engineers object to the Scherzer lift, on account of the combined rolling and horizontal movement, tending to wrench and tear the abutments to pieces. This matter seems to be a fit subject for discussion in your paper, in order to bring out the opinions of engineers competent to pass upon this question: Would it be desirable or safe to place the working parts of a rolling-lift bridge 5 to 7 ft. below the high-water line, or to use this type of bridge in a navigable stream where there is ample width for pivot piers and a swing span, which could have its floor at a lower level? A. P. B.

Saginaw, Mich., Jan. 21, 1902.

The Safety of the Brooklyn Bridge: A Rejoinder by Messrs. Duryea and Mayer to the Letters of Messrs. Hildenbrand and Henning.

Sir: In your issue of Jan. 16 appear long replies by Mr. Gus. C. Henning and Mr. Wilhelm Hildenbrand to our recent report on the safety of the Brooklyn Bridge.

We should find the replies of Mr. Henning and Mr. Hildenbrand more worthy of serious consideration if they did not so often misquote our report and ascribe statements to it which it does not contain. A large part of Mr. Hildenbrand's reply consists of elaborate arguments to prove the falsity of statements and assumptions which he ascribes to us, but which we never made. Frequent instances of this will be pointed out as we proceed.

The instructions from the District Attorney, who "instigated" (as Mr. Hildenbrand says) our examination and report, were as follows:

To make an examination of the bridge. . . . with a view of ascertaining whether or not the capacity of the bridge is overtaxed at the present time, and as to whether or not the bridge has been allowed to deteriorate because of improper supervision, inspection and repair, and to report as to all facts bearing upon the question as to whether or not there was neglect on the part of the persons who had charge of the bridge.

It is evident that in ascertaining the responsibility for any defects found, it was necessary to separate those due to the design from those which were due to changes or lack of care since the bridge was completed; otherwise great injustice might be done the Bridge Department officials in charge of the bridge when the accident occurred.

It is acknowledged in the report that the suggestions for removing defects go beyond the strict meaning of the instructions; it seems ungracious, however, to merely point out defects without suggesting any remedies, and this addition to our report was commended by the District Attorney as being necessary to its completeness.

In saying that we criticised the design and not the designer, we meant exactly what we said, not at all what Mr. Hildenbrand states we must have meant, and our expression contains no sophistry. No one has any doubt that Watt and Fulton and Stephenson were designers of very exceptional ability, and at the same time no one doubts that Watt's steam engine and Fulton's steamboat and Stephenson's locomotive would, if compared with the "standards of the best present practice," be open to very severe criticisms.

Mr. Hildenbrand regrets that our report did not pronounce the bridge either absolutely safe or absolutely unsafe. Neither statement could have been truthfully made, as you have well shown in an editorial reviewing our report. Structures may be absolutely safe or absolutely unsafe, but there is a rather wide zone between, in which the only truthful verdict is uncertainty. This bridge, if it were the property of a first-class railroad, would not be considered so unsafe as to prevent its continued use, but it would be considered so unsafe as to render immediate strengthening of the weak parts advisable.

Mr. Hildenbrand quotes us as saying the bridge is not overloaded, because the *sum* of dead and live loads is about the same as originally intended. We do not say so, as the report expressly states that live load produces in many parts of the bridge much larger stresses than an equal dead load. The actual live load was also much less when the bridge was first completed than now. We were therefore unable to say truthfully what Mr. Hildenbrand says we should have stated—that the bridge is as safe now as when first completed—his inference as to what we should have said being based on a misstatement of what we did say.

Both Mr. Henning and Mr. Hildenbrand plainly state that they think the floors of suspension bridges should have a standard of safety all their own, and not be governed by the rules of safety which long practice has determined to be necessary for truss bridges. It is true, as they say, that injury to trusses or floor beams does not affect in any way the safety of the structure, if they mean by structure merely cables and towers, but such injuries do affect very materially the uninterrupted use of the bridge, the confidence of the public, and may even cause the death of a few passengers.

Good details in trusses and floors and bad details causing secondary stresses are entirely independent of whether the trusses and floors occur in suspension bridges or in other bridges; and the experience in other bridges with which we are credited can be applied to these floors and trusses without modification. This experience will contrast very well with that of Mr. Hildenbrand, when, at the age of 24, he began his work on the design of the Brooklyn Bridge. His experience gained subsequently on other suspension bridges can hardly be held to have had any retroactive effect on his designing for this his first bridge.

There was no necessity for making the testing of the materials in the bridge a part of our inspection, even if time had permitted it. The steel was said to have been given the usual shop tests during its manufacture and to have fulfilled the specifications. No one should know better than Mr. Henning (who made these tests) that no subsequent deterioration was possible from electrolysis or "crystallization," or even—except in a very few cases—from fatigue of metals. Mr. Hildenbrand's assumption that "bridge trains run at the rate of 40 miles per hour may have made the rods brittle" is rather amusing. The speed of the hauling cables is only 11.3 miles per hour, and no speeds even faintly resembling 40 miles per hour have ever been used on the bridge.

Mr. Henning says that the working stresses adopted by us prove that we assumed the trusses and floor beams to consist of low steel. If he had taken the trouble to read our report, he would have found given, under the head "Strength of the Materials in Structure," the ultimate strengths and elastic limits as prescribed in the official specifications which governed his inspections of the materials. In the same place he would have found both our assumed working stresses and our reasons for adopting them. One of the reasons was that high steel made at that early date could hardly have had the same uniformity and reliability as steel of the same hardness made to-day, it being well known that although high steel was used in the earliest bridges, its general use was soon abandoned for softer grades. The facts given by Mr. Henning—that the first machines for making eye-bars were made for this bridge ("the first all-steel bridge"), and that the upsetting of rods was not then practicable—shows conclusively the immature and experimental state of the manufacture of steel bridge members at that date.

Mr. Henning states that it is the common practice to use larger working stresses in structures of large dimensions. So it is, but not in the *floors* of such structures. One of the necessities in the adoption of a high working stress is that the stresses in the structure shall be calculable with certainty and some precision; the design of this bridge does not permit this. It is noticeable that while Mr. Henning states that our working stresses in the floor are unfairly low, the official report of the Bridge Department by Messrs. R. S. Buck and H. A. La Chicotte (reviewed by us in the "Engineering Record" of Jan. 11) expresses the opinion that our working stresses are somewhat too high.

Mr. Henning thinks we should have used a higher ultimate strength for the cable wire. That which we accepted was the minimum strength required by the specifications governing its acceptance. The average strength has no bearing on the question, especially as secondary stresses are involved.

Many contradictory claims are made as to the strength of this wire. The specifications permit the use of any wires having an ultimate strength not less than 160,000 lbs. per sq. in. and an elastic limit not less than 47% of its ultimate strength. Colonel Roebling states that the *average* strength is 170,000 lbs. per sq. in.; Mr. Hildenbrand that the minimum ultimate strength is 172,000 lbs., and the average 177,000 lbs., while the minimum elastic limit is 66%; and Mr. Henning seems to state that the minimum ultimate strength is 180,000 lbs. per sq. in. It is evident that not all these statements can be true, and we prefer to accept the limit given in the specification, with which only the manufacturers could be forced to comply.

The cables of the Brooklyn Bridge were the first ever made of steel wire, and so little was then known of steel that Colonel Roebling felt called upon to make an elaborate defence of its adoption. The small knowledge of steel at that time is well shown by the specification requirement of only 47% as the minimum elastic limit of the wire, about 66% being the actual minimum now according to most authorities. As stated in an editorial in your issue of Nov. 30th, 1899, "steel making in 1876 was a different art from what it is now."

As to our assumed working stress for the steel wire, 60,000 lbs. per sq. in., if it errs in any way it is in being too high. The preliminary calculations of the New East River bridge were based on a working stress of 55,000 lbs. per sq. in., and a minimum ultimate strength of 180,000 lbs. When the contract was let the ultimate strength specified was 200,000 lbs. and we do not believe that this change was accompanied by any reduction in the size of cables.

Mr. Henning asserts not only that our working stresses are unduly low, but that we always assume stresses in the structure of the greatest amount. This is not true, as we assumed an adjustment which would give smaller stresses than one which may actually exist. We also used the average stress of the four cables, when the stress in one or more of these cables is undoubtedly more than this average. In each cable, the actual stress in some wires may be more than in others because of differences in length, and each wire is weakened somewhat by the splices—neither of which facts was used by us. Our secondary stresses in the cables at the center of the main span were based on the saddles being immovable. Should they move (as both Mr. Henning and Mr. Hildenbrand assume they may) the middle point of the cables would be lowered more than we assumed, and the angle in the cables—and consequently their secondary stresses—would become larger than those of our report.

The saddles were not assumed to be fixed because of a personal examination, though one was made. This assumption (as stated in the report) rests on measurements furnished us by the bridge department, which show that the saddles have remained in the same position winter and summer for several years past. A table (not printed in Engineering News) was given in "Engineering Record," Oct. 12, 1901, containing a selection from these measurements. The report does not state that the saddles cannot move because the stays bear on the masonry, but that they cannot move without slipping of the stays. We were aware that the saddles did so move in the accident of 1898, and that no special harm resulted from it, notwithstanding which, such movements by jerks can hardly be called desirable.

The slip joint is spoken of by Mr. Henning as not forming a true hinge—meaning, we presume, that its construction does not allow of the formation of an angle here. Mr. Hildenbrand also made this contention until we furnished him with measurements showing the lost motion. He devotes considerable space to showing that no angle can be formed because the tongue has a machine fit, with only 1-16-in. play, and later acknowledges the actual play to be 3-16-in. to 9-16-in. Our examination indicates that there never was a "machine fit."

The actual play is enough to allow most of the angle or bending in cables given in the report, but even if it were not, Mr. Hildenbrand's computations with 1-16-in. play are erroneous. He calculates the bending in the short tongues but neglects entirely the bending which must take place in the chords at the same time, over a length of about 18 ft., or 9 ft. each side of the center. He also bases his computation on a force of 36 tons, quoting this as that used by us, when the force actually given in our report is 36 tons from each half span, or 72 tons in all.

Mr. Hildenbrand gives a computation of his own to show the bending in the cables at the center of the main span and ends up by *assuming* that the curve of cables is a circle for a length of 6 ft. at center. He then calculates the radius of this circle for two different loads and temperatures and from this the bending stress. He seems to forget that the only point at issue is the curvature of the cables at the center of the span, which he assumes. He gives no reason whatever for his assumption, and his elaborate calculation is therefore valueless.

His illustration of how, according to our theory, "by making the cable weaker we make it stronger!" is also valueless. The combination of cable with truss somewhat resembles the case of a small continuous stick bound to a large hinged stick. If the large stick is turned through a certain angle the small stick must bend at the hinge, and it is evident that the less the diameter of the small stick the easier it will bend and the less will be its bending stress for this angle. This is a fact and not, as Mr. Hildenbrand calls it, an absurdity.

The case of the cable and truss is much more complicated, however, since the cable consists of wires sliding upon each other by friction, the friction increasing as the diameter of cable decreases. It is also evident from its derivation that our theory applies to round cables and not, as assumed by Mr. Hildenbrand, to flattened cables. Notwithstanding the more intricate calculation, however, it still remains a fact that the bending stress produced in the cable by bending it through a fixed angle will decrease as the diameter of the cable becomes smaller.

Various other points are brought forward against our method of computing the bending stresses in the cables. These points could all be shown to be fallacious, but the subject is so intricate and lengthy that the attention of but few readers could be secured. We will therefore let the matter rest with the comments already given, except to say that Mr. Hildenbrand misquotes our statement that the computations on which our conclusions are based are necessarily incomplete and inexact by omitting the immediately following qualification that they are complete enough and exact enough to justify our conclusions.

Our report does not say—although Mr. Henning says it does—that seven suspenders broke on the day of the accident. What it does say is that seven rods and two cable bands were discovered to be broken on that day, and that two of the rods had been broken for a long time. Neither does it say that "the north cable hangs 7 ins. higher than the others, and that the suspenders have not been lengthened accordingly;" on the contrary, it states that "the distance from cable to floor beam was and is greater at the northernmost cable than at any other," and in the table in "Engineering Record" referred to the excess distance is given as 5 ins. to 7¾ ins.

Referring to the breaking of the short suspender rods and to wind stresses in them, we cannot agree with Mr. Hildenbrand's venerable "crystallization" theory, nor—as we have already remarked—with the existence on the bridge of any such cause as speeds of 40 miles per hour. We have apparently not made ourselves clear as to the existence of wind stresses in the cables and suspenders at the center of main span and shall now endeavor to do so.

All suspender rods are "fixed" in direction laterally to the bridge by the trunnions at their lower ends and any lateral pull on the rods must cause bending stresses in them. When no wind is blowing the rods evidently hang in the plane of the cable without lateral pull. Suppose, for a moment, that the cables will have to withstand all the wind pressure acting on their area and that the platform must withstand all the wind on its area, or that there is no transference of wind pressure from platform to cables or vice versa. The cables and the platform would then resist the wind as two separate systems, the former a very flexible one, but with a very small wind surface; while the latter is more rigid but with a very large wind surface. Each system would, if it could act independently of the other, deflect laterally until it had balanced the force of its own wind pressure, but as the wind loads and rigidities of each system are entirely independent of those of the other, it is evident that only by the merest accident could the deflections be the same in the two systems, or even nearly the same.

In the actual structure the two systems are connected together by rods which are fixed in direction and, at the center of the main span, only about 18 ins. long. It is very evident, then, that as the two systems are rigidly connected at the center of the span, their deflections at this point (except as modified by the slight spring or bend of the rods) must be equal. It is also evident that the only thing which keeps the deflections from being unequal is the presence of these short fixed rods, and that these rods can do this only by reason of a side pull which will cause bending in them. A little thought shows also that, even if the two systems would deflect alike if unconnected, the change in the planes of cables would even then cause some side bending in the short rods; that it is change of direction which causes side bending in the rods, and that any lateral motion of the structure tends to change their direction.

Mr. Hildenbrand states that he has observed the Brooklyn Bridge in a gale when "the stiffening truss on the windward side of the bridge appeared to be perfectly

straight, while the cable made a visible curve inward." It is hard to see how the cable could move off and separate itself from the platform without some objections from the short fixed suspender rods. He should admit that in this case, at least, very heavy bending stresses from wind must have existed in the short rods.

The "perfect straightness" of the stiffening truss must have been a matter of appearance only. A gale when it was "impossible to stand without holding on with a firm grip to some fixed object" represents a very considerable wind pressure and consequent lateral force on the platform. The structure must resist this force as two cantilevers built out nearly 800 ft. from each tower and aided by a 3-in. diameter parabolic wind cable of nearly 1,600-ft. span and very flat versine. Mr. Hildenbrand much overestimates the lateral stiffness of the structure. It does not (though he says it does) possess a "complete system of wind diagonals, similar to the lateral bracing in any truss bridge," "in addition to . . . an extensive system of under floor stays and two parabolic horizontal storm cables." As a matter of fact there are no wind diagonals except wire ropes, whose connections and sections give much less rigidity than such wind diagonals as are used in truss bridges. The tightness of the storm cables (only one of which, unless they are under great initial tension, can act at a time) is very dependent on the temperature, and their comparative looseness in summer allows a considerable lateral deflection of the platform before they can begin to do much work, and with their long span and small versine, any stretch from either temperature or tension will be accompanied by a considerable increase in versine. The truss could remain "perfectly straight" only if the wind force produced no stresses in the structure, or if the stresses produced no elongation or contraction in the metal.

The illustration already given, showing that because of the short rods the deflections of the two systems must be the same at the center of span, may also be used to show the existence of bending stresses from wind in the cables. If the cables were free to deflect laterally without interference from the trusses, their horizontal projections (because of cradling) would be parabolas both before and after deflection, and in each case the vertex of the parabola would be at the center point of the span, and there would be no angle in the cables at this point. The horizontal projection of the chords of the stiffening trusses would be a straight line from tower to tower before the lateral deflection occurred. These chords are cut at the middle of the span and have practically no resistance to bending here, while at all other points in the span the platform has considerable resistance to bending. The horizontal projection of the chords after deflection would therefore be approximately two straight lines, meeting in an angle at the center of the span.

As the cables and platform near the center of the span are connected rigidly to each other laterally by the short suspender rods, they must deflect together and their horizontal projections after deflection must be almost alike. It therefore follows either that the cable will bend the platform laterally into a parabola, or that the platform will bend the cables to its own shape and so produce a lateral bend in them at the center of the span. As the platform is much stiffer than the cables, it is evident that the cables must conform to it and that the wind pressure will therefore produce a lateral bend in the cables at the center of the span. It is also evident, as the only connection between the platform and the cables is by means of the suspenders, that the only way in which the platform can bend the cables into its own horizontal shape is by means of side pulls in the short suspender rods, and that the short suspender rods next to the center of the span will therefore be subjected to much greater bending stresses from wind than will any of the other rods.

Mr. Hildenbrand says that he obtains a side deflection of 1.2 ft. at center of span by assuming a maximum stress for parabolic wind cables and for under floor stays of nearly one-half their ultimate strength. While we have no plans which show them, the span of the wind cables is about 1,550 ft. and their versine not more than 110 ft. Being wire ropes made of 150,000 lbs. wire their ultimate strength is probably about 135,000 lbs. per sq. in. of metal, and the stress assumed by Mr. Hildenbrand was about 65,000 lbs. per sq. in. If the leeward cable is under this stress in winter when the maximum wind may coincide with the lowest temperature, its maximum stress in summer would be about 22,000 lbs. per sq. in. less (by assuming its temperature expansion = 1-1,200 and E = 26,000,000), or 43,000 lbs. per sq. in. from wind alone. The windward cable would at the same time (with a summer temperature and the maximum wind load) be under a zero tension—or the initial stress in each cable in the hottest summer and with no wind blowing would be about 21,500 lbs. per sq. in. As the maximum stress in summer could be only 43,000 lbs. per sq. in., the difference between this and the initial tension, or 21,500 lbs. per sq. in., is the entire allowable strength of the leeward cable to prevent deflection. This tension would cause a stretch of about 1.29 ft. and this stretch, with the span and versine assumed, would mean a lateral deflection of 3.4 ft. If the cables have a smaller initial stress in summer (as is more than likely) the deflection necessary to make the maximum stress as great as Mr. Hildenbrand assumes will be still more. He says that the lateral deflection of the floor at the center of span will be 1.2 ft. when the storm cables are stressed to nearly one-half their ultimate strength; we say, that, under the adjustment most favorable to small deflections, a deflection of at least 3.4 ft. must occur before the stress in the storm cables can become so large.

Mr. Hildenbrand states that we calculated the bending stresses in the masonry of towers "under the assumption that the saddles are immovable and that the middle span be loaded with the maximum load while the land spans are free from moving load" and calls this "a very unnatural and improbable supposition." We agree with him that this supposition is very improbable—and as we never made it, we do not feel called upon to either defend or explain it. He will see, if he will only read our report, that *our* assumption was that the land spans be loaded with *half* the maximum moving load. *His* assumption—*no* moving load on the land spans—would give a maximum compression in the tower masonry of about 58 tons per sq. ft. instead of the 39.4 tons given in our report.

A great deal has been said about the "high-class masonry of which the Brooklyn Bridge towers are constructed." We have no doubt it is very good masonry, but can see no reason why it should be spoken of as a class by itself, or why it should be considered any better than that generally used nowadays in all first-class bridges.

Mr. Hildenbrand speaks of the Board of Engineers who reported in 1894 on the New York and New Jersey Bridge. The members were Messrs. C. W. Raymond, G. Bouscaren, W. H. Burr, Theodore Cooper and G. S. Morison, and they are, as Mr. Hildenbrand says, "all engineers and bridge builders of great experience and of the highest reputation." The following extract from their report may be of interest in this connection:

> In proportioning these piers, your Board has found it necessary to adopt limits of stress. They have based their estimates on the supposition that the pressure between the metallic bed-plates and the top of the masonry should not exceed 20 tons to the square foot, and that the pressure within the masonry and on the foundation should nowhere exceed 10 tons to the square foot. . . . While these pressures have been exceeded in some structures, they are higher than usual practice, and call for masonry of good quality and more than ordinary cost.

One of the members of this Board, Mr. Morison, used much higher pressures in a study subsequently made by him of a bridge design for the same location. He says:

> It is proposed to make these piers of an exceptionally good class of masonry and to allow a maximum pressure of 20 tons per sq. ft. on the granite, and of 72 tons per sq. ft. on the under side of the casting which supports the tower. While these pressures may seem excessive, it must be remembered . . . that the pressure in the central section of the East River Bridge towers, at the level of the roadway, is 28 tons per sq. ft.

This quotation makes it quite apparent that Mr. Morison, with the example of the Brooklyn Bridge before him, considers 28 tons per sq. ft. as too high a pressure, and one too far outside the limits of good practice, to be adopted by him.

It will be noticed that our report gives the maximum pressure of 39.4 tons per sq. ft. as referring to the Brooklyn tower only. The New York tower was built after the Brooklyn tower and is 3 ft. wider and its maximum pressure consequently much less. It seems that the designers themselves could hardly have been suited with the (supposed) 28½ tons maximum pressure in the Brooklyn tower, since they went to considerable expense to make the pressure in the New York tower smaller.

It is noticeable that Mr. Hildenbrand's table of high pressures in masonry does not contain a single bridge structure or a single example of American practice.

In criticising our suggested improvement of the stiffening system, Mr. Hildenbrand credits us with a plan which differs fundamentally from that contained in our report, and then makes an elaborate calculation to prove that *his* plan (not ours) is a very bad one. We proposed to introduce anchorage bents near the middle of the short spans, at the same time making the saddles movable and preventing bending stresses in the cables by removing the wrapping wire where necessary. Mr. Hildenbrand assumes that we proposed to leave the saddles fixed and to do nothing to obviate bending stresses in the cables. Then (incidentally assuming *no* moving load on the land spans instead of the one-half maximum which was our assumption) he makes his calculations to the ten-thousandths of a foot, and finds that the stresses are very bad in the absurd plan which is his creation, and not ours.

Only one other point of Mr. Hildenbrand's letter will be taken up, his criticism of our stresses in the intermediate floor beams and in the channels (along the outside high truss) supporting them. He starts out by selecting as the load on a trolley track an 8-wheel car weighing 37,500 lbs., although in our report we state that 4-wheel cars of 32,400 lbs. are in use on the bridge, and that they must be used in the calculation of the floor. The intermediate floor beam must take the weight of one axle, which would be 16,200 lbs. if the 4-wheel car is used, and only 12,500 lbs. for Mr. Hildenbrand's 8-wheel car. He then—although he evidently regards the intermediate floor beam as a continuous girder—neglects the weight of one trolley wheel entirely.

Starting with his erroneous load, he then proceeds by an erroneous method to calculate stresses which are entirely different from those which his loads would produce. He uses a new principle for calculating continuous girders, his method being to assume that each panel is a girder fixed at both ends. The results of Mr. Hildenbrand's calculations therefore do not show the unreliability of our stresses—but they do show his utter carelessness in selecting his loads and his reliance on erroneous methods of calculation.

We agree with him that "it is not necessary to give more examples" and that "the matter is serious and important enough to deserve study and a thorough examination." If he had given our report the study and examination he recommends to us, the result would have been a considerable saving of time for both him and ourselves, and a great saving of space in your columns.

Edwin Duryea,
Joseph Mayer.

No. 1 Broadway, New York, Jan. 21, 1902.

Notes and Queries.

With reference to the letter of Mr. John F. Wallace on placing the Isthmian Canal work in charge of an engineering commission (Eng. News, Jan. 16, p. 53), it should be said that Mr. Wallace addressed the letter to us as a member of the civil engineering profession, and not as an officer of the railway company with which he is connected. The addition to his signature of his title as an officer of the Illinois Central R. R. was made in this office, merely to indicate Mr. Wallace's address in Chicago.

THE REBUILDING OF THE AUSTIN DAM at Austin, Tex., is under consideration by the water and light commission of that city. The commission has appointed a citizens' committee of 12 members, including Messrs. John D. McCall and Fred. A. Scott, to co-operate with the city officials in devising plans to rebuild the dam.

THE DYNAMITE EXPLOSION ON THE NEW YORK RAPID TRANSIT RAILWAY.

An accidental explosion of a quantity of dynamite stored in a frame shanty located on a platform over one of the shafts of Section 4 of the New York Rapid Transit Railway, which occurred about noon on Jan. 27, caused the death of six persons, injured more or less severely about 125 others, and resulted in the widespread damage of adjoining buildings. Section 4 of the New York Rapid Transit Railway extends from 33d St. to 41st St., on Park Ave. It is one of the deep tunnel sections, and the construction consists of two parallel double-track tunnels through rock, which pass under the present double-track street railway tunnel, which will be remembered by those of our readers who have visited New York as passing under the local elevation of Park Ave., known as Murray Hill, just to the south of the Grand Central Station, on 42d St. The two tunnels are being excavated from shafts, and the shaft at which the explosion took place was located just south of 41st St. On one side of the avenue, opposite the shaft, is the Murray Hill Hotel, and on the other side is the Manhattan Eye and Ear Hospital; looking down Park Ave., and fronting on 42d St., a little over a block away, is the Grand Central Station of the New York Central & Hudson River R. R. On the same side of the avenue as the Eye and Ear Hospital, and between 41st and 42d Sts., is the Grand Union Hotel. To the south of the Murray Hill Hotel and the Eye and Ear Hospital both sides of the avenue are bordered by typical brownstone New York residences. The principal damage was done to the buildings which have been named.

The accounts of the explosion, and of how it came to occur are conflicting, but the damage done is plainly evident, and is easily described. At the shaft there was a deep hole about 20 × 15 ft. in lateral dimensions, comprising the cribbed walls of the shaft and part of the adjoining street and sidewalk, into which had fallen part of the platform and the derrick and hoisting engine, which it supported, together with several hundred bags of cement and other debris that filled up the tunnel headings at the shaft's bottom. The west wall of the street railway tunnel adjoining this hole was blown in for a length of about 40 ft.; and the car tracks were buried beneath its debris. Altogether the damage to the rapid transit tunnel work and to the street car tunnel above it were insignificant. Two of the killed were employees of the contractor for the tunnel. Above the surface, however, the explosion wrought general havoc.

A hasty examination of the adjacent buildings by the engineers of the Department of Buildings

showed no serious structural damage to any of the.... The Murray Hill Hotel, which was the building nearest to the center of the explosion, had all the windows on its Park Ave. front blown out, and the rooms to which they gave light were filled with the wreckage of furniture and ceilings and with debris from the street. Two guests and two employees were killed. The Eye and Ear Hospital had most of its windows blown out, and had suffered wreck only a little less severe than the hotel opposite. Along the facades of the Grand Central Station and of the Grand Union Hotel the majority of the windows were shattered, and similar damage had been done to the residences to the south for a block south along Park Ave. From this storm center, if the term may be permitted, the damage extended in all directions for two or three blocks, decreasing in severity as the distance increased, and consisting chiefly in the breaking of windows and the destruction of plastering. To a careful observer the vagaries of the explosive force, as evidenced by the resulting wreck, were very striking and curious. Between two houses which had lost practically every window, would be seen another in which nearly every window was intact; in some cases the basement windows would be broken and those of the upper stories uninjured, and in other cases the exact contrary was the case. Some of the large plate glass show windows in shop fronts were forced inwards and others were forced outwards.

Turning now to the cause of the explosion, only a few definite facts are available at the present writing. There are, however, a multitude of conflicting rumors. The storage place for the dynamite has already been described. According to Mr. Ira Shailer, M. Am. Soc. C. E., the contractor for Section 4 of the subway, there was never stored there at one time more explosive than his permit from the Fire Department allowed, namely, 62 lbs. District Attorney Jerome, who, with his assistants, began collecting evidence shortly after the accident occurred, is quoted as saying that so far as he had been able to find out, about 250 of 300 lbs. of explosive had been delivered at the storage place in the morning, and that all but 100 lbs. of this had been used in the previous blasts. The colored man who was in charge of the stored explosive testified that at the time of the explosion there were in the shanty 13 boxes, containing from 50 to 75 cartridges of dynamite each. This same man is also responsible for the only detailed statement which has so far been obtained of how the accident occurred. According to this statement, the shanty was lighted by a candle in a small lantern, which was placed on a shelf above where the explosive was stored. This lantern was jarred off the shelf by the shock of a blast in the tunnel heading, and ignited some paper on the floor. An attempt was made to extinguish the fire, but before this could be done the flames had reached the explosive. The explosion followed immediately after. Various comments have been made on this statement, and on the probable amount of the explosive which was detonated, the most authoritative of which is the following quoted from Mr. Wm. Barclay Parsons, M. Am. Soc. C. E., Chief Engineer of the Rapid Transit Railway, in the New York "Sun" of Jan. 28:

Before I make an investigation myself I do not care to make much of a statement. I will say this, however, that all these stories of vast quantities of dynamite being stored in the tunnel that people did not know anything about are untrue. In the first place, the rule has been adopted in the work on the subway of having only the amount of dynamite needed for a day's operations at any section of the line. Blasting at this particular spot begins at the commencement of work in the morning and should end, according to the regulations, about noon or not later than 12.30. Only the dynamite needed for that time has ever been on storage there. This rule is followed by all the contractors, and we considered it a very safe rule.

I don't care to go into figures regarding the amount of dynamite until I have investigated matters myself. It should be remembered, however, that only a half hour of the blasting time remained, and in that time probably one more blast, and not more than one, would have been set off; consequently only a fragment of the day's store of dynamite was left to explode besides that which it was intended to set off. I don't believe that more than a case of dynamite remained. How this came to explode I don't know surely, and I don't want to venture any opinion without being positive. That will all be determined.

The reason why it did so much damage, why the shock was so great, is perfectly plain to engineers. It was because it went off in the open and there was nothing to take the force of it up, as in the case of dynamite set off in rock, where its force is spent in shattering the rock. It only takes a little dynamite to cause a tremendous shock under those conditions, and from the force of the shock yesterday people at once jumped to the conclusion that tons of dynamite had exploded, which, as I have said, is untrue.

In conclusion it may be noted that both the District Attorney and the Coroner have begun an investigation of the cause of the disaster, and will make their findings known at an early date. The damage to property, which is variously estimated at from $150,000 to $300,000, as well as the damages resulting from loss of life and injury to persons, will have to be paid by the contractor.

INVESTIGATION OF THE PARK AVE. TUNNEL COLLISION.

The investigation before a coroner's jury of the Park Ave. tunnel collision of Jan. 8 was concluded on Jan. 24. The principal witness examined was Mr. Wm. H. Newman, President of the New York Central & Hudson River R. R. The examination was principally directed to ascertaining the division of responsibility among the officers of the company. We quote as follows from the report of the testimony printed in the "New York Times:"

Q.—What authority has Mr. Franklin [the Manager of the tunnel line] north of 52d St? A.—Full charge of the operations. Everything except the construction and maintenance of the property.

Q.—Does the company consider it a part of his duty to examine the signal system and make changes if necessary? A.—To call for changes.

Q.—Did you, as a man with 30 years' practical experience, expect a railroad man with a training as a conductor to be a fit man for handling traffic over the Harlem line north of 52d St.? A.—I don't know of any class of employees that knows more than conductors regarding the best methods of handling trains over a track like that.

Q.—Do you think a conductor's experience fits a man for determining the best system of signals? A.—I presume a man experienced in signals was chosen.

Q.—Did you find out? A.—I believe we have the best signals to be obtained. Chief Engineer Wilgus has charge of the installation and maintenance of them.

Q.—Do you know Mr. Wilgus's qualifications to supervise these signals? A.—I believe he is fully competent, and one of the best engineers in the country.

Q.—Who is the person responsible for the signals? A.—Mr. Franklin, for their operation; Mr. Wilgus for their installation and maintenance.

Q.—Who is responsible for their defects if there are any? A.—That depends upon the manner of defect.

Q.—Is it anybody's duty to see if the signals can be improved on? A.—It is the duty of Mr. Franklin, of Mr. Wilgus, and of myself to see that proper and efficient methods are used to safeguard the passengers.

Q.—What have you done to discharge this duty, to see that the signals are abreast of the times? A.—We have used every known method. By examination and comparison with other systems.

Q.—Your master carpenter has testified here that with 10% increased cost you could rebuild and safeguard your cars, so that they would be as safeguarded as private cars? A.—Cars are being made stronger every month, when they are rebuilt. We are using every effort to make them as safe as possible. The same safety appliances put on private cars are now being put on coaches.

Q.—What do you think of the Division Superintendent who for ten years receives complaints of engineers running by signals—do you think it his duty to keep them to himself or to report to you? A.—Engineers run by signals on every road in the country.

Q.—Where there are congested tracks and short blocks it is important that the lights be seen? A.—Yes. We have in the tunnel the best possible system of signals and management. We have always the demand of the public that trains get in early in the morning. We are confronted with the difficulty of congestion and of getting the trains through the tunnel.

Q.—Is there any provision in your management for the man controlling the Harlem line to report that competent engineers cannot see the signal lights? A.—Every one connected with the railroad realizes the danger of handling trains in the tunnel. I presume if he (Franklin) had known of a better system he would have suggested it.

Q.—Who is responsible for improvements? A.—You might say the owners of the property—the stockholders.

Q.—What officer's duty is it to get something better in signals, if possible? A.—Everybody's who has the interest of the corporation at heart—I, the directors, the stockholders, and others.

Q.—That's the most definite responsibility you can find? A.—The men primarily responsible are the men in charge of the system—Mr. Wilgus and Mr. Franklin.

Q.—To what do you attribute the accident? A.—It is the duty of an engineer to stop when the signals are against him.

Q.—Suppose he didn't see them? A.—You can make a thousand suppositions. No man can tell what caused the engineer not to stop. It was human fallibility. If anybody can suggest a better method we will be glad to adopt it.

Q.—You're adopting a better method now? A.—To relieve congestion. We will adopt it if we can get proper legislation.

Q.—Will the improvements conduce to safety? A.—Anything will that will relieve the congestion.

Q.—Why wasn't it done before? A.—Now is the time that traffic increase demands it.

The verdict of the coroner's jury was as follows:

We find that the said William Leys came to his death on the 8th day of January, 1902, at 56th St. and Park Ave., in this city, in the tunnel of the New York Central & Hudson River Railroad, by compound fracture of skull, caused at the time and place aforesaid, due to the fact that locomotive engine attached to south-bound train No. 118X of the Harlem Division of the New York Central Railroad, controlled by John M. Wisker, locomotive engineer, collided with and partially demolished the rear car, in which deceased was a passenger, of train No. 223Y of the New York, New Haven & Hartford Railroad, which said last-named train was nearly stationary, owing to the failure of the said John M. Wisker, locomotive engineer, to stop his said locomotive at danger signal at 59th St., which was properly set, thereby indicating that the said New York, New Haven & Hartford train was in block.

We further find that the said engineer, John M. Wisker, owing to the heavy atmosphere, due to weather conditions, together with the pressure of large bodies of steam and smoke escaping from trains passing on various tracks in said tunnel, obscuring said signal, was unable to locate said danger signal.

We further find faulty management on the part of the officials of the New York Central & Hudson River Railroad, and we hold said officials responsible for the reason that during the past ten years said officials have been repeatedly warned by their locomotive engineers and other employees of the dangerous condition existing in said tunnel, imperilling the lives of thousands of passengers, and they have failed to remedy said conditions; and also for the reason that certain improvements in the way of both visible and audible signals could have been installed, and this disaster thereby have been avoided, and for the further reason that no regulation of speed at which trains should run in said tunnel has been enforced, thereby allowing engineers to exercise their own discretion.

THE INVESTIGATION BY THE STATE RAILROAD COMMISSION.

The New York State Railroad Commission held an inquiry into the causes of the collision, and means to be adopted for bettering the conditions of operation of the Park Ave. tunnel, on Jan. 23 and 24, and is to continue its investigation on Jan. 29.

At the first day's session, Chief Engineer W. J. Wilgus, M. Am. Soc. C. E., was the principal witness. He testified that the most practical plan of improvement of the tunnel would be to entirely remove the roof and make it an open cut, with bridges at the street crossings. He said it is impossible to ventilate the tunnel by any system of fans, on account of the passage of trains in opposite directions, and the conflicting air currents resulting. All railway tunnels for which fan ventilation has been used, said he, are single-track tunnels. Further, if a system of ventilation were used, it would be necessary to close the present surface openings, and if that were done, and some accident interrupted the operation of the ventilating apparatus, passengers in any trains which had to stop in the tunnel would be in danger of asphyxiation.

Turning to the matter of limitations to the traffic movement, he said that the present limit was set, not by the capacity of the tunnel or the station, but by the yard in front of the station. While there are four tunnel tracks, the tracks through the side tunnels converge to a junction with the central tunnel tracks at the upper end of the station yard, so there are really only a single outgoing and a single incoming track at this point, over which all trains must pass. At present the average number of trains passing through the tunnel daily in both directions is about 575, including in this all movements of empty car trains, and locomotives running light. These latter constitute a large part of the train movement. At present, on account of the limited yard-room at the Grand Central Station, trains of cars as fast as they are emptied have to be hauled north to the Mott Haven yards and hauled back again when they are needed for use.

To obviate unnecessary train movement, property has been acquired for the enlargement of the yards at 42d St., and the yards are to be altered so that two outgoing and two incoming tracks can at all times be used.

In addition, electric traction is to be adopted for suburban trains, which will be run through the side tunnels, and an underground loop terminal with a separate suburban station is to be built at 42d St. for these trains. Plans of the terminal exhibited by Mr. Wilgus show a double-track loop quite similar to that built at the South Terminal Station in Boston. This loop will be about 18 ft. below the surface, or about on a level with the mezzanine floor of the Rapid Transit station close by. From this mezzanine floor, passengers will descend to the island platform between the Rapid Transit express tracks.

The suburban trains will be equipped with motors on the multiple-unit system, but electricity will not be used beyond Mott Haven. At this point a steam locomotive will be attached.

To carry out this entire work will take, Mr. Wilgus thought, about two years. He was asked whether anything could be done to improve the safety of the tunnel at once and give temporary relief during the carrying out of the alterations, but he could not say that the company had any plans to do this, nor could he make any suggestions to that end. Apparently the intention of the

company is to use the central tunnel for all through trains, which will be continued to be hauled by locomotives.

Mr. Charles Whiting Baker, editor of Engineering News, who was called by the Railroad Commission to give evidence as to the feasibility of ventilating the tunnel, testified that it was entirely practicable to establish a system of forced ventilation for the tunnel that would clear it of smoke and gas in the interval between trains and give a clear view of the signals for the engineer of the following train. He said that railways generally had been backward in the provision of ventilating apparatus for tunnels, as compared with the progress made in mine ventilation, etc.; but within the past few years more attention is being paid to the ventilation of tunnels. He referred to the tunnel under the Mersey River, at Liverpool, the Pennsylvania R. R.'s Baltimore tunnel, and the St. Louis tunnel as examples of tunnels ventilated by fans. The ventilation in the St. Louis tunnel, he said, was far from satisfactory; but this was because the ventilation plant was far too small to meet the requirements, and not to any fault of the system itself.

The Park Ave. tunnel he considered a remarkably easy tunnel to ventilate as it was so near the surface. To get the best effect, the tunnel, which is two miles in length, should be divided into a number of blocks, say, from four to ten. An exhaust fan and stack should be placed at the center of each block, with inlet openings admitting air to the tunnel midway between the fan stations. It was simply a matter of making the fans and the inlet and exit passages large enough to produce any degree of ventilation desired. There is nothing patented or patentable about such a system. The machinery could all be purchased in the open market and the entire cost would be only a moderate amount. There need be no risk of accident from the breakdown of the ventilating system. If any fan were put out of service, its work would be done by the fans on either side, by proper adjustment of shutters in the air inlet openings. The metalwork about the ventilating apparatus would not be so likely to corrode as will the metal structure which the company is now putting inside the tunnel to support the roof, for the locomotive smoke and steam would be greatly diluted by the fresh air. This dilution would also prevent the discharge from the tops of the stacks from being noticeable, and the stacks themselves could be so designed as to be inconspicuous and not offensive to the eye.

If any difficulty were found from the contrary movement of trains in the central double-track tunnel, a thin partition wall could be placed there to convert it into two single-track tunnels, so far as the movement of air currents is concerned. Such a partition would also prevent the smoke and steam discharged when two trains pass each other from obstructing the view of the engineer.

Manager J. H. Franklin testified that to make the entire tunnel a single block, as advocated by a New York daily paper, would absolutely stop the movement of traffic, as trains could not be put through the tunnels fast enough. Locomotive firemen are forbidden to fire soft coal going south after passing Woodlawn on the New York, New Haven & Hartford or Spuyten Duyvil on the New York Central. He knew of no way to remove smoke and gas from the tunnel except to remove the roof. He acknowledged that the proposed changes will still leave the main tunnel obstructed by smoke and gas, and that the signals will to a certain extent be obscured.

Mr. John V. Cade, Secretary of the Standard Signal Co., of Troy, N. Y., testified as follows, according to the "New York Times" report:

Q.—How does the Central's signal system compare with those in operation in other tunnels? A.—I think the system installed in the Central's tunnel is as perfect as any I know of, and in some respects more safeguarded than any I know of.

Q.—Can you suggest anything that will add to the safety of this system? A.—Can suggest nothing to make it safer that wouldn't add such complications as would result in greater danger than there is at present.

Q.—Multiplication of safety devices leads to confusion? A.—Yes.

Q.—Can you suggest any change that would conduce to the safety of operation? A.—No, Sir.

Q.—Would you take out any signals? A.—If I was in charge of the signals and the company allowed me, I would take out the gongs and probably the torpedoes, and get down to the cold fact that the engineer must see the signal—the clear signal, not the danger signal—before he goes ahead.

Q.—Would the stationing of men at the signals to place torpedoes on the track conduce to greater safety? A.—I think not. English railroad men in this country to study American methods have told me that one of their chief difficulties is the unreliability of these men. This gives the engineers an excuse when accidents do happen.

Mr. Chas. H. Platt, General Superintendent of the New York, New Haven & Hartford R. R., and formerly in charge of the Grand Central Station and approaches, said that after the collision in 1891 he experimented on various forms of signals, and finally settled on the system at present in use. The "Sun" quotes his further testimony as follows:

One hundred and twenty millions of people have been carried through that tunnel and there has never been an accident save by the failure of the human equation, which cannot be eliminated from the transportation problem. There is no track in this or any other country so safely signaled as the Park Avenue tunnel. All these signal systems, such as a light in the cab, a whistle in the cab, the automatic setting of the brakes, are of no use because they go on the theory that unless a danger signal is out everything is safe, which is fundamentally wrong. The higher the development of these devices the worse they are, because they start wrong.

At the session on Friday, Mr. Chas. L. Addison, Supt. of Transportation of the Long Island R. R. Co., testified that the signal system in the tunnel is the best standard system at present in use. The obscurity of signals in the tunnel is due to the steam rather than the smoke from the locomotives.

Mr. Wm. Barclay Parsons, M. Am. Soc. C. E., Chief Engineer of the N. Y. Rapid Transit Commission, said that the only two remedies he could conceive of for the tunnel's condition were to remove the roof or adopt electric motive power. He did not think artificial ventilation practicable because the smoke and steam could not be removed fast enough. He thought the changes proposed by the railroad company would effect a material improvement, and by lessening the congestion of traffic would reduce the chances of accident by probably 50%. The lighting of the tunnel would add nothing to its safety for operation. For clear signals, an entirely dark tunnel with no other light than the signal lamp is the ideal condition.

Wm. E. Rogers, who was a member of the New York Railroad Commission in 1891, described a plan for ventilating the tunnel which the Commission had favored after the accident of 1891. He thought the railway company had never given a fair trial to plans for ventilation.

Capt. Wm. M. Folger, of the U. S. Lighthouse Board, testified concerning the signal lamps in the tunnel. He thought it would be an advantage to use ground and polished lenses instead of pressed glass. Oil, he considered a more reliable illuminant than electricity.

Mr. D. B. McCoy, Division Supt. of the New York Central, referred to the oft-repeated suggestion that passenger traffic should be transferred to the company's west side line, with its terminus at 30th St. and the North River. He said 15 to 18 passenger trains daily use this line, but it is impossible to induce the public to patronize it largely.

Mr. W. B. Appleyard, Master Car Builder of the New York, New Haven & Hartford R. R., said the wrecked cars were stronger than a Pullman car. They had had a general overhauling in October, 1901, and were in first-class condition. He admitted that some of the recently-designed cars with ends strengthened by steel construction might have made a better showing in the wreck.

Adjournment was then taken to Jan. 29.

On Jan. 27, the Railroad Commission issued the following order:

The Board of Railroad Commissioners hereby recommends and directs, as immediate and preliminary means for the lessening of dangerous conditions and the securing of safe operation in the New York & Harlem Railroad tunnel, in New York city, the following:

1. That no train be allowed to run at a greater speed than 18 miles an hour in the Fourth Ave. tunnel, under existing conditions of terminal facilities.

2. That no cars carrying passengers in which oil is used for illuminating purposes be hauled through said tunnel.

3. That no engineer be detailed or permitted to run a locomotive engine through or in said tunnel in sole control of said engine until after he has made at least 25 trips over each track through said tunnel, being [illegible] in all, under the pilotage and instruction of an engineer who has had experience of at least two years in running engines through said tunnel; that a record be made and kept on file in the office of the manager of the New York & Harlem line, so called, of each day of such probationary running, giving the date and time of such runs, the tracks over which such runs were made and the name and term of service of the probationary engineer and of the instructing engineer or pilot.

4. That no soft or bituminous coal be used for the stoking of locomotive furnaces while running through said tunnel, nor shall any locomotive be moved into or through said tunnel unless the fire then in its furnace shall be in a coked and incandescent state or condition and has ceased to discharge black smoke. In the event that the fire needs restoking while in or passing through the tunnel, such restoking shall be made with charcoal, coke or anthracite coal.

These four recommendations and directions to take effect within 24 hours after the service hereof upon an officer of each of said companies.

5. That in the signal lamps used in said tunnel the lenses be ground, instead of pressed, the pressed lenses to be replaced as soon as practicable; also that the green glass in the signal lamps in said tunnel be replaced with a proper lighter shade of green as soon as practicable. Also that all of these signal lamps be supplied, as soon as practicable, with circular wicks, instead of flat wicks.

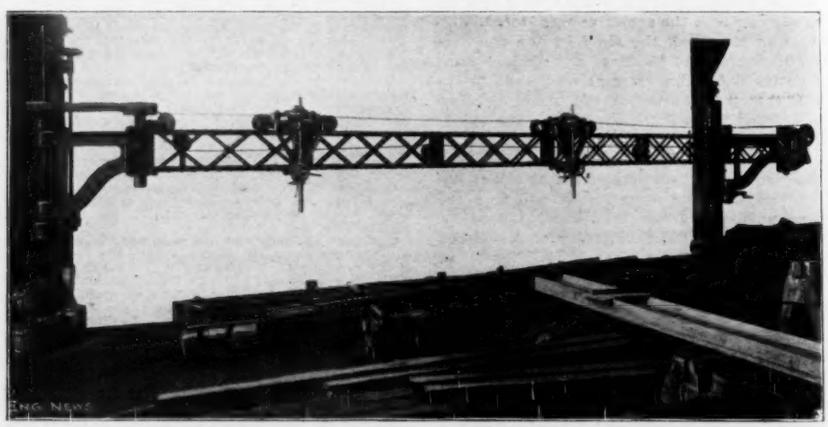
That the companies shall notify this board within three days after the service hereof upon an officer of each of said companies when these recommendations and directions will be complied with.

By the Board,
John S. Kenyon, Secretary.

The Board has also caused a bill to be introduced in the New York legislature empowering the Board to order the discontinuance of the use of steam locomotives in the Fourth Ave. tunnel.

A NEW FORM OF DRILLING MACHINE FOR BRIDGE AND STRUCTURAL WORK.

The novel form of drilling machine shown in the accompanying view, called by the makers "Swinging Drilling Machine," is designed for the use of structural and bridge shops, for drilling rivet and pin holes in steel shapes. The frame of the machine consists of a riveted steel girder running between two adjacent supporting columns of the building, and pivoted to these columns by means of swinging bracket-arms. On the girder are mounted two drilling heads, which can be moved along the girder and clamped at any desired point. The drill spindle is fed to the work by hand, but the whole machine can be raised or lowered by power by means of elevating screws



A SWINGING DRILLING MACHINE FOR STRUCTURAL WORK.
Built by Niles Tool Works Co., Hamilton, O.

acting on the swinging brackets, which latter are mounted on suitable slides bolted to the columns. The drill spindles are driven, by means of a round belt running over sheaves in the manner shown in the illustration, from a vertical shaft belted to a countershaft.

This style of machine can evidently be adapted to varying conditions. The machine shown in the illustration has a beam 40 ft. long and 20 ins. deep, the columns being 38 ft. 9 ins. apart. The elevating gears give the spindle a maximum working range between 2 ft. and 7 ft. from the floor. Each drill-head has a maximum travel along the beam of 34 ft. The machine is adapted for the full range of sizes of drills used in work of this class. The driving belt runs over three-step cone pulleys, and the drillheads are back-geared, giving six speeds of drilling. The machine requires about 4 HP. for its operation. An attachment for horizontal reaming can be applied.

The machine is built by the Niles Tool Works Co., of Hamilton, O., and is already in use in several bridge shops.

THE SAVANNAH HARBOR CONTRACTORS' TRIAL for conspiracy with ex-Captain Carter to defraud the Government, is to be held in the U. S. District Court at Savannah, beginning on Feb. 11.

A LABOR BUREAU has been established by the Society for the Protection of Italian Immigrants at 17 State St., New York city. The society has been recently organized by a number of well-known philanthropists to aid Italian immigrants and protect them from frauds and ill-treatment. Eliot Norton, Esq., of 135 Broadway, is its President.

THE PURIFICATION OF SEWAGE BY SEPTIC TANKS AND VARIOUS SUPPLEMENTAL PROCESSES.*

By W. S. Shields.†

The first year of the new century has established the fact that the septic tank has passed the experimental stage and is now a fixed and important principle in the purification of sewage, and although there is much to learn regarding its use and management, its function is recognized and its principles fixed. The septic tank has come to stay.

In accepting the septic tank as a natural means for the purification of sewage we must not expect too much of it; it is not a complete process in itself, but a preparatory step, and must be followed by other agents which will furnish sufficient oxygen to oxidize the remaining ammonias and suspended organic matter.

Examples are becoming too numerous where engineers and city officials have built tanks of this character, copied, in many instances, without alteration from successful plants and incorporated into systems varying widely in conditions and character of sewage. They have expected equal results and have been much disappointed to find that the plant does not work well and the odors are very bad. This, however, is but a natural consequence, and will continue until the public can recognize that there is science even in this humble art, and that skill and experience are essential to the proper disposal of their own refuse.

The septic tank has yet some elements of uncertainty and only time and usage will enable us to study it thoroughly. The skill of the chemist and bacteriologist, as well as the engineer, must be employed to discover its best arrangement, time of passage, and the conditions which will produce greatest reduction of sludge and odor.

It is doubtful if there is much merit in the submerged inlet and outlet. In fact, our best results have been with the inlets at the surface, or the center of the inlet pipe at the water line of the tank, with baffle boards some 3 ft. in front, to spread and direct the flow downward. The outlet, a wide weir protected by another baffle board; and in some of our flexible tanks where the flow is made to pass through several long and narrow compartments the baffle board is omitted entirely without any apparent bad results.

It is also doubtful if the air-tight tank has any advantages, either in increased efficiency or in the prevention of odors. Comparison of effluents, so far as the senses can detect, is not in favor of the tight tank, but rather of a freely ventilated, yet warmly-constructed building over the tanks where the gases can readily be diffused into the air as they are thrown off. The practice of the writer's firm is to recommend masonry tanks, with interior divisions for different time of passage, covered with a low brick building with walls 6 ft. high, with a wood gable roof finished with good quality of felt roofing; a door in each end, a few windows, and good-sized ventilators in each gable. Without such ventilators the woodwork soon becomes saturated with dampness and decays very rapidly. This form of construction is not unsightly, gives full access to the entire tank, and where the final treatment requires a distributing tank it can readily be placed in the same building.

While the tank alone must be depended upon for the septic treatment, there is a wide range in the methods and materials which the engineer may select in his design for works to further or complete the work of the tank. The object being to furnish sufficient oxygen to arrest the septic action, consume the ammonias and oxidize the organic matters suspended in the effluent.

This may be done by dilution with sufficient running water, by carrying it a sufficient distance through wide shallow channels, by broad irrigation on land, by intermittent filtration through beds of sand, broken stone, cinder or other available materials; by contact beds, either single or double; or by some of the numerous forms of continuous or intermittent filters of peculiar and special construction.

So wide a range is there in this form of construction that there are but few localities or conditions found which do not afford some means for economical construction; but without an intimate knowledge of all details of the subject and the value of the various materials as filtering mediums, there is great danger of failure and a useless expenditure of money. I think many of our engineers are attaching too much weight to the English practice, for conditions of climate and sewage strength vary greatly in this country from English conditions, and from this cause I fear there will be recorded within the next few years some failures; and yet even these must need be that we may the better learn. In the construction of works for the purification of septic tank effluent the efforts of the next few years will be to some degree experimental, the simplest and nearest to nature's fixed formulas will win a place in common practice. Some methods will be found adapted to special conditions, while others will be rejected and the plants revised into other forms of treatment.

Experience has demonstrated that the contact beds, when properly controlled and managed, will produce excellent results, but there is danger of their falling into discredit for lack of proper and skilled care. The necessity for regularity of filling and emptying by manual labor is a serious disadvantage and but few automatic devices can be found in the market which have proved successful in continued service.

The great expense of building water-tight tanks for contact beds is another serious item, especially throughout our Western states, where so many of our cities are well up to their limit of bonded indebtedness. In many instances their cost prohibits their use, even when conditions are favorable.

The single contact beds, while they do not give results equal to the double, are open to the same objections, unless the plants now nearing completion where the beds are built in natural earth excavation, prove successful, and even then it is a question whether better results cannot be secured by covering their surface with a layer of sand and using them as intermittent filters.

Of specially constructed aerating filters there is no end, and with the exception of the cases where forced aeration is secured the practice is somewhat experimental, and only results will demonstrate their efficiency and durability.

The writer has had some interesting experience during the last year with two plants in which local conditions made the septic tank, followed by sand filtration, the most economical method to adopt. Being granted considerable latitude (except as to cost) as to the carrying out of our plans, we were able in both cases to produce a very satisfactory effluent, and at an extremely low cost for construction.

SEPTIC TANK AND SAND FILTER BEDS AT WAUWATOSA, WIS.

At Wauwatosa, Wis., the plant has been in operation since Sept. 1, 1901, handling 100,000 gallons of sewage per day, with practically no cost of operation. It has, however, a visit of sometimes once a week, and often twice a week from the superintendent of public works, a gentleman of high mechanical ability; his inspection consists of recording the visits, the number of fillings recorded by the counter, temperature, etc., in extreme weather; spending perhaps from a quarter to a half hour each visit at the plant. The six filter beds, with a total area of one-fourth acre, are dosed in rotation by means of a dosing tank and a siphon device, which discharges some 5,500 gallons of septic tank effluent at a dose onto each bed in rotation. This device has operated without fault since its installation and through weather which was once — 20° F.

The record shows that at one visit, when the temperature was — 4° F. outside, the interior of the septic tanks was + 2°, the water at both entrance and discharge of the tank was 48°, the water in dosing chamber some 200 ft. distant from the septic tank was 47°, and the final effluent at outlet to river was 44°.

At no time during a week of extreme cold weather did the sand beds fail to work, although cakes of ice 6 or 8 ins. thick formed upon their surface. The interior of the septic tank was covered several inches deep with hoar frost, but no ice formed upon the surface of the tanks except in one unused compartment. The final effluent is clear and sparkling and the cost of the plants, exclusive of the land, was $5,370.

SEPTIC TANK AND SAND FILTER BEDS AT LAKE FOREST, ILL.

At Lake Forest, Ill., the only available site for a plant was on a narrow sand beach between a high clay bluff and the water of Lake Michigan, where the construction of piers to protect property from the eroding effect of the waves had collected a triangular beach of an acre or more in extent. The sand being already in position, the same scheme was adopted as at Wauwatosa, and the plant consists of a septic tank and dosing chamber in one building, with ten 10-in. Miller siphons discharging upon ten sand beds of equal size, and having a total area of ¾ acre. The surface of the beds is some 7 ft. above the lake level, and is protected from wind by a board fence, and from the seas by breakwater piers. Owing to the lateness of the season the sand beds were frozen several feet in depth before sewage was turned upon them and so far, while good results have been obtained, the frost still remains and causes some trouble and annoyance, which could not occur had the sewage been available before deep freezing.

This plant has a safe capacity of 200,000 gallons of sewage per day, and was built at a total cost of $8,000, including lake shore piers and other protections. Much importance in both plants is attached to regular and intermittent feeding of the sewage to the beds.

The use of siphons for discharging the contents of the dosing chamber is very satisfactory where plenty of fall is available for storage or heading up, but it is impossible in many cases to get the required head without pumping, which fact has necessitated another form of device which can control the flow without loss of head. The 10-in. siphons can be operated with 18 ins. depth of water and with bottom of bells 12 ins. above the bottom inverts of the outlet limb. The siphons at Wauwatosa, operating under 24-in. head, discharge 5,500 gallons in 7½ minutes, while at Lake Forest, working under 30-in. head, the tank was emptied of 8,000 gallons in 10 minutes.

Both of these plants will receive our care and attention until they prove themselves able to continue their present efficiency or develop defects which will be studied and if possible remedied.

It is the hope of the people along the Lake Shore north of Chicago, that the plants at Glencoe (see Eng. News, Oct. 24, 1901—Ed.) and Lake Forest may demonstrate that all sewage can be purified before being allowed to enter the lake from which their water supply is obtained, and unless unforeseen disaster overtake these plants they will demonstrate that it will be possible for Evanston, Wilmette and Winnetka to join in one common plant, and treat the sewage of this district in a satisfactory manner at one-fifth the cost of the proposed open waterway which at best is of doubtful value as a sanitary measure.

One very essential element which we Western engineers must contend with, and which our Eastern brothers do not fully appreciate, is the limitation of funds available for such purposes as sewage purification in the great majority of our Western cities. People in Western towns, as a rule, have to be more economical than in the older and more wealthy Eastern cities, and it is difficult in this section of the country to raise sufficient money to carry out such improvements as are found necessary. We see our Eastern engineers spending anywhere from $40,000 upward for sewage purification work, which we for Western cities of even greater population must accomplish within a small fraction of such amounts. Our work, therefore, appears so far insignificant and of small account; our consolation, however, must be in the fact that it is not the engineer who expends the largest sum for public improvements who displays the most skill, but he who can accomplish the most effective results for the amount available is, perhaps, the one who renders truly efficient service.

*A paper, slightly condensed, read before the Illinois Society of Engineers and Surveyors, at Joliet, Ill., Jan. 22 to 24, 1902.

†Of Alvord & Shields, Consulting Engineers, Hartford Building, Chicago, Ill.

COST OF COMPRESSED AIR HAULING IN A MINE.

In a paper on the subject "Compressed Air Haulage Plants," read before the Engineers' Society of Western Pennsylvania on Nov. 19, 1901, Mr. Richard Hirsch gave some data on the cost of hauling by compressed air locomotives in a Pennsylvania mine, which are of interest. The mine is Colliery No. 6, of the Susquehanna Coal Co., at Lyon, Pa. The hauling was formerly done by mules, of which over thirty were in use; the present motive power equipment consists of two compressed air locomotives, cylinders 7 × 14 ins., tank capacity 130 cu. ft., tank pressure 500 lbs. per sq. in., built by the H. K. Porter Co., of Pittsburg, Pa. The weight of each locomotive is 16,000 lbs. During the year 1897, the plant was operated a total of 179 days. The cost of operating for the year 1897, and the corresponding cost of the old style of mule-hauling, is summarized thus:

Total cost of plant, except steam boilers, cars and track	$15,156.00
Operating expenses, including all labor, fuel, supplies, repairs, etc.	2,202.78
Fixed charges, including interest, depreciation and renewals	1,776.60
Cost of mules required for same work	4,062.48
Cost of operation by mules, including labor, supplies, interest, depreciation, etc., for 179 days	11,328.63
Cost of operation by compressed air	3,979.38
Saving by use of compressed air	$7,349.25

At this rate of saving, the entire cost of the compressed air plant would be saved in 361 working days.

The average daily work of these two motors during the period of 179 days referred to was 1,185 net ton-miles, or the cost of hauling was 1.9 cts. per net ton-mile. The corresponding cost of hauling by mules would be 5.34 cts. per net ton-mile. Had the compressed air plant been operated for 300 days in the year, instead of 179 days, at the same daily rate of work, the cost per ton-mile would have been considerably less than that given above.

CONCRETE SEWER CONSTRUCTION AT COLDWATER, MICH.*

By Harry V. Gifford, Jun. Am. Soc. C. E.†

The concrete sewer constructed at Coldwater, Mich., last fall is, so far as the writer knows, the first one of its design ever built. The city of Coldwater has a population of 6,216 (census of 1900), and is built upon an exceedingly flat stretch of ground. The streets have never been properly graded, and some 15 years ago an 18-in. tile sewer, built with "ring" joints without the ring and laid with a carpenter's level, was built for a trunk storm-water sewer. From year to year branch after branch has been added, regardless of size or anything else, except that it would furnish a temporary drainage for an individual's property. The result was that in time of storm the capacity of the trunk sewer was too small, and the backed-up water would flood the sidewalks and lawns.

During the past summer, the firm of Riggs & Sherman, of Toledo, O., was called in to design a new trunk sewer, and decided upon a circular sewer 3½ ft. in diameter. The subsoil which underlies about 18 ins. of hardpan is a loose gravel of excellent quality, very free from clay or organic impurities, and in limitless quantities. Wolverine American Portland cement could be obtained for $1.35 a barrel, delivered on the work. These facts, among others, led the engineers to recommend a sewer built entirely of concrete. Bids were asked on three separate designs: (1) brick; (2) concrete, with the invert a monolith 8 ins. thick and semicircular in form, and the arch composed of 11 concrete blocks; (3) concrete, built entirely of blocks. The detail plan of these blocks called for a

Fig. 1. Concrete Sewer with Arch Blocks and Monolithic Invert; Coldwater, Mich.
Riggs & Sherman, Consulting Engineers, Toledo, O.
H. V. Gifford, Engineer-in-Charge, Toledo, O.
C. W. McKinney, Contractor, Toledo, O.

length of 24 ins, the intrados to conform to the arc of the sewer, subtended by a chord 5¾ ins. long, the extrados a chord 8 ins. long, the coursing joints being 8 ins. through. The lowest bid was $3.40 per lin. ft. for brick and $3 per lin. ft. for concrete, with block arch and monolithic invert. Some of the councilmen had favored brick, as being cheaper, but the bids bore out the claims of the engineers that the concrete sewer would be cheaper, and the contract was let at $3 per lin. ft. The general construction is shown in Fig. 1.

Some 8,500 blocks were required, and in order to give them as much time as possible to set, the majority of this work was done before excavation on the trench was started. Molds were made of 2-in. lumber, and lined with tin, and the four sides of the mold formed the extrados, intrados, and two ends of the block, the remaining two sides being open, and the whole held together by screw or wedge clamps. The molds were not at first lined with tin, but after a little use the concrete stuck to the sides when the mold was removed. The tin entirely remedied this difficulty. The mold when put together was laid upon a mold-board, 1 × 12 × 30 ins., reinforced by cleats across the bottom. When the block was completed, the mold was carefully taken apart and mold-board and block were carried out and laid down upon a stretch of sand that had been leveled off to receive them. The block was left upon the board until, by careful handling, it could be removed without injuring it. The length of this time depended entirely upon the weather; varying from 24 to 48 hours. After being removed from the board it was laid upon the ground and allowed to remain there for 3 days, after which it was placed upon the pile. After the blocks were 24 hours old, they were sprinkled with water from a garden hose several times each day for at least a week, and in all handling great care was exercised to protect the inside face. Very few blocks were broken, which was rather remarkable, considering their weight of 90 lbs. each and the green condition in which they were handled. Fig. 2 shows the molds and the completed blocks laid aside to set.

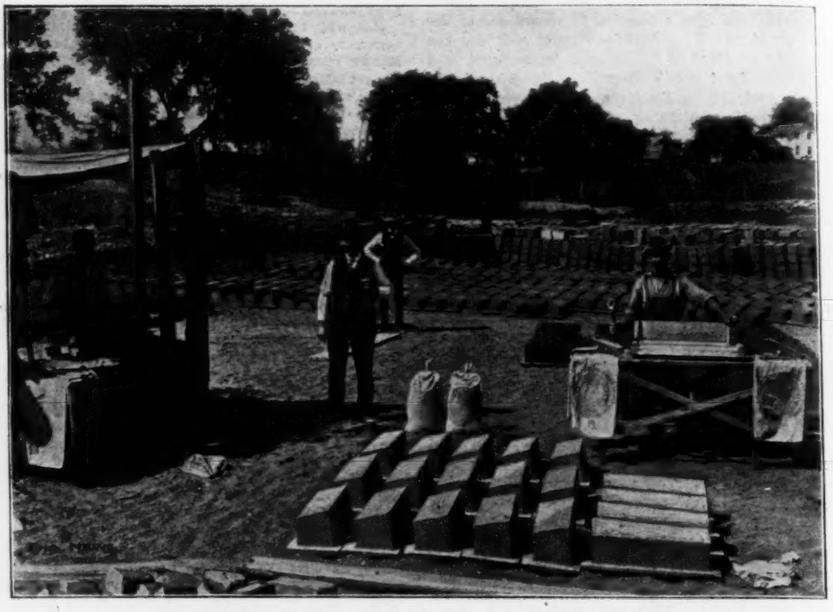


FIG. 2. MANUFACTURING ARCH BLOCKS FOR CONCRETE SEWER.

A gang of 14 men was all that could be readily worked in the space available: 2 men to screen gravel, 4 to mix concrete, 4 molders, 3 men to shift and water the blocks, and 1 foreman. The work was done in a gravel pit owned by the city, and this materially reduced the cost of the blocks because of less expense attached to the handling of the gravel. Another thing which worked great benefit to the contractor was the fact that he did not have to pay for the gravel, but to offset this he afterwards gave the city whatever gravel it needed, from the trench. With a little practice, each molder could turn out 175 blocks a day. Each batch of concrete containing half a barrel of cement would average 18 blocks. This would make the cost of each block between 11 and 12 cts., figuring in 0.85 ct. on each block for use of molds and mold-boards, which were entirely lost. It is believed that it would have been more satisfactory had the blocks been 18 ins. long instead of 24 ins. Although a man can make a block 24 ins. long about as quickly as the shorter one, and it is not necessary to handle as many blocks to build a given distance of arch, yet the greater rapidity and ease with which the smaller blocks can be handled and the decreased liability to break or chip them, would offset the advantages of the longer block, from the contractor's standpoint as well as that of the engineer.

The gravel obtained from the bank was of an excellent character, and very free from clay or other impurities. A stratum of pebbles from which all the sand had been washed ran horizontally through the bank. These pebbles when caved down and mixed with the gravel below easily balanced whatever surplus of sand occurred in the other gravel. This was all screened through a screen with 1-in. meshes. The concrete was mixed in the proportion of 1 part Wolverine Portland cement to 6 parts of gravel, screened through a riddle of ¾-in. mesh. The only point of interest in connection with the mixing was the proper amount of water; if too much water was used the concrete would stick to the molds, and after the molds had been removed, would fall apart, or at least lose its proper shape. On the other hand, if not enough water was used, the outside, and especially the corners, would dry out before the concrete had set. This made the block liable to crumble. It was found that the proper consistency was such that when smartly struck with the back of a shovel, moisture would appear on the surface, or such that, after being rammed in the mold, water appeared upon the sides of the block.

The material encountered in digging the trench was the same loose clean gravel that we got from the pit, with the exception of the bottom foot or two, which, in some places, was a sandy loam. Every foot had to be sheathed and thoroughly braced, and constant watch kept on the banks even then, for they would crack off in long stretches from 3 to 5 ft. back of the sheathing. The horizontal method of sheathing was first used and proved quite disastrous to the contractor, for in driving it down it greatly increased the natural tendencies of the banks to cave. It could not be as easily handled as the vertical form, and after the top part was removed, the banks would cave, making it impossible to get out the lower courses. In fact, the method is ill-adapted to the character of ground at Coldwater, and after we had started to use the vertical method, the work progressed much more rapidly and satisfactorily. With the exception of going under the main line and four side tracks of the L. S. & M. S. Ry. with a cut of 15 ft., no particular difficulty was experienced in the excavation.

When the trenching had reached the approximate grade of the center line of the sewer, stakes were driven in the bottom about 5 or 6 ft. apart, and in a line equal to the distance of the radius, plus the thickness of the shell, plus ½-in. each side of the center line, as determined by a plumb bob from lines on the surface. These stakes were driven to such a grade that the top of a 2 × 4-in. stick or runner set edgewise upon them would be the proper grade of the top of the invert. The invert was then excavated to approximately conform to the outside of the finished sewer, and was then made to exactly conform by a semicircular templet of the proper dimensions, drawn along the runners. Where gravel was found in the bottom it was impossible to hold the shape exactly, but where loam was found, the excavation could be made perfectly true. Concrete was then thrown in and with shovels and rammers was worked into approximate form without the use of molds. The only difficult part was to get the inside shoulder on both sides to stand up square. This could be accomplished by holding a float or a board along the inside, filling in behind it with concrete and tamping it down. We tried the use of a form in making the invert, which was built very much like the center used for arches of brick sewers, except that about one-

*Abstract of a paper read at the annual meeting of the Michigan Engineering Society, at Grand Rapids, Mich., Jan. 9.

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third of the center of the arc was left out. This form was about 6 ft. in length and was suspended in an inverted position from cross boards resting upon the runners. The bottom of the invert for about one-third of the semicircle was made to approximate dimensions; the form was then set on the runners over this partially prepared spot, and concrete was filled in on both sides, between the outside of the form and the side of the trench, and thoroughly rammed. The form could then be lifted off and the invert trued up. This gave very good results, the only objection to it (and an objection which was great enough to cause its rejection) was that the form was too large and clumsy, and was in the way of the workmen. It could be used with success in a soil where the excavation could be prepared a number of feet ahead, so that the form could be drawn along as each section was completed, but in such soil as that at Coldwater, where the placing of the concrete must closely follow the preparation for the invert, this form was in the way.

Either method gave an approximate form to the concrete, which was trued up by means of a semicircular templet with a radius of 21½ ins. This left the surface of the concrete ½-in. larger than the finished invert. While the concrete was yet green, a heavy coat of mortar, composed of 1 part of cement to 2 parts of sand, was roughly trowelled on. This in turn was brought to its true dimensions by drawing along the runners, a third semicircular template with a 21-in. radius. This left the surface perfectly true, and both concrete and plaster of proper thickness, the finished thickness being 8 ins. The surface resembled a concrete walk finished with a float. We tried smoothing it down with a trowel, but when a templet was applied to a section thus treated, it was found to be so far from its true form that the practice was given up after the first day. When finished, it was much smoother and truer and offered less resistance to the flow of water than the invert of a brick sewer. The templates were held in place and prevented from moving laterally by plates of sheet iron which were fastened to the projecting arms of the template and fitted against the inside faces of the runners. This secured the proper thickness for both concrete and plaster and incidentally prevented a bill for extras by the contractor on that score. Fig. 3 shows the invert under construction.

When the coat of plaster had become so hard that a man could walk upon it without injuring it, two tiers of blocks were laid up to a line upon either shoulder of the invert. The mortar was composed of 1 part of American Portland cement, 2 parts of sand, and ¼ part of slacked lime plaster. This lime made the mortar so much richer and so much better to work, and the joints were so much better laid, that it fully offset what little weakening effect it had, if any.

The centering was then put in place and the rest of the arch built up, care being taken to break joints. As each section (about 8 ft. in length) was completed, a thin grout of equal parts of cement and sand was poured over the top, and worked into all the joints. Gravel was thrown upon each shoulder of the arch and tamped down to prevent spreading, and the center then struck and moved ahead. In backfilling we tried to arrange to cover at least 18 ins. over the top of the arch and let it stand for 24 hours, but in some cases where several feet of earth was filled in before the arch was 12 hours old, observations failed to disclose any dislocation of the arch-blocks or injury to the invert.

At manholes, a hole about 3 ft. diameter was left in the arch. The manholes were built of brick, commencing on the top of the invert at either side, and were built upon and dovetailed into the arch. Pipe connections were made by setting one joint of pipe in place and building the concrete around it as the work progressed. A bulkhead was built at the river with a concrete foundation 2 ft. deep, 3 ft. thick, and 14 ft. long, the upper part being of rubble masonry, one end of which was dovetailed into the wing of an adjoining abutment. A coping was built of concrete 4 ins. thick. In some catch-basins that were afterwards built, we made use of some of the surplus blocks. The excavation was made as usual and a 6-in. foundation of concrete was laid. Upon this 25 blocks were set upon end in a circle, every other one being a half block. On top of each half block a whole block was laid, then the brick work was started, building up the lower ones until level with the higher ones, and completing the catch-basin with ordinary brick work. This simply suggests one more use for concrete.

The degree of strength to which the sewer will ultimately attain is indicated by the following incident. We had occasion to cut a hole through the invert for a 15-in. connection, when the sewer was about a month old. The trench had been excavated to the bottom of the sewer on the outside and two men provided with heavy cold chisels and hammers, one on the inside and one on the outside, occupied a day and a half in cutting the hole. To ascertain the tensile strength of the concrete, the writer made some tests at the laboratory of the Michigan Portland Cement Co., with proportion of 1 part of cement (taken from sacks on the work) to 6 parts of sand. Four briquettes broken after 12 hours in air and 12 hours in steam, averaged 215 lbs., the maximum being 250 lbs. This accelerated steam test is, I believe, approximately equivalent to the seven-day test.

In Washington it is the custom to pave the inverts of concrete sewers with vitrified brick, but it seems to be a question whether the ordinary wear in a storm-water sewer is so great that a ½-in. coating of rich Portland cement plaster will not withstand it. Certainly, neater work can be done by omitting the brick. An objection which might be raised against the concrete sewer, would be that in places where manufacturing wastes are carried, certain acids might have a disintegrating affect upon the concrete. That might be true in a combined system, but even then it could be provided for by coating the inside with tar or asphalt. The greatest objection would

Fig. 3. Building Invert of Concrete Sewer.

be that the cost would be greater than that for a brick sewer in certain localities, and sufficient information is not obtainable to state in what degree this objection would hold. In Wilmington, Del., a brick sewer was built on a stone cradle at a cost of $14.84 per ft. This sewer was afterwards extended, built entirely of concrete, at a cost of $10.20 per ft., using crushed stone instead of gravel. The sewer at Coldwater was cheaper than a brick sewer would have been. In almost any locality, gravel or crushed stone can be obtained without excessive cost, and in almost any place east of the Mississippi River, good cement can be obtained at a reasonable figure. When we take into consideration the increasing strength and durability of concrete in the ground, it would seem that at no very distant date the brick sewer must look for a strong rival in concrete.

Messrs. Riggs & Sherman, of Toledo, O., were the designers and originators of the construction above described as well as consulting engineers for the work; Mr. C. W. McKinney, of Toledo, O., was the contractor, and the writer was engineer in charge of construction.

In the discussion of this paper, Prof. M. E. Cooley, of the University of Michigan, gave particulars of tests made by him of the concrete used in the sewer blocks. Two test blocks were used, 24 ins. long, set on supports 20 ins. apart for the transverse test. The first block (No. 1) was 7¾ ins. wide on top, 5¾ ins. wide on the bottom and 7¾ ins. deep. The other (No. 2) was inverted, 5¾ ins. wide on top, 8 ins. on the bottom and 7¾ ins. deep. Block No. 1 required 4,280 lbs. to break it across, while No. 2 took 4,530 lbs. The broken halves were then roughly squared and tested for compression, with the following results:

Block No. 1:					
1st end, 57,340 lbs., or	1,100	lbs.	per.	sq.	in.
2d end, 52,110 lbs., or	998	"	"	"	"
Average, 52.2 sq. ins.	1,049	"	"	"	"
Block No. 2:					
1st end, 63,400 lbs., or	1,190	"	"	"	"
2d end, 52,770 lbs., or	991	"	"	"	"
Average, 53.25 sq. ins.	1,090	"	"	"	"

ANNUAL CONVENTION OF THE ILLINOIS SOCIETY OF ENGINEERS AND SURVEYORS.

The seventeenth annual meeting of this society was held at Joliet, Ill., Jan. 22, 23 and 24, the headquarters being at the Munroe Hotel, and meetings being held in Castle Hall. At the opening meeting on the afternoon of Jan. 22, an address of welcome was delivered by the mayor, Mr. Richard J. Barr, who referred to the arbitrary limitations which the Illinois legislature imposes upon municipalities in regard to their expenditures for public works. He also urged a larger attendance of city engineers at meetings of the League of American Municipalities. This address was responded to by Mr. Emil Rudolph (Chicago), Vice-President, after which the annual address was delivered by the President, Mr. H. G. Paddock, City Engineer of Moline.

The regular business of the convention was then proceeded with, and Mr. J. W. Alvord (Chicago) presented the report of the Committee on Sewers, which opened with the encouraging statement that sewer work in Illinois is being carried on with more intelligence and good judgment than ever before. The proportion of cities which disregard their sanitary problems is growing smaller every year, and comparatively few independent sewers are now constructed without the aid of a general plan prepared by an engineer. Reference was made to the large intercepting sewers now under construction in Chicago, the largest (on 39th St.) being 20 ft. diameter, and built partly in tunnel on the pneumatic system, with a shield. During the past year, four cities have constructed septic tanks: Lake Forest, Princeton, La Grange and Glencoe. Several new sewer systems have also been designed and constructed. The committee particularly noted the increasing use of double-strength pipe for sizes above 12 ins. diameter.

A discussion on "The Shrinkage of Earth in Embankments and Trenches" was then taken up, Mr. Kuehn and Mr. Paddock speaking in regard to railway and city work respectively. Mr. J. B. Ashley (Chicago) described trouble in compacting sand filling in trenches 5 ft. deep with side slopes of 1 to 1. Flooding with water and trampling with horses produced little effect and eventually the ridge left on top of the trench was cut down and carted away, but two years later there were no signs of further settlement. Tests with tamping damp sand, flooding the sand, and depositing sand in water showed that greater density could be obtained by the last-named method. Mr. A. H. Stevens (City Engineer of Joliet) stated that flooding the trenches while backfilling works well with both clay and gravel.

A paper on "Water Supply for Small Cities" was then read by Mr. G. W. Chandler (Canton, Ill.), which referred to the growing importance of water supply for small inland cities, where, with no river, lake or stream, wells form the only source of supply. He described the development of the water supply system at Canton, Ill.; the city has had two serious fires to demonstrate the inefficiency of the system in use at the time, and now has a 6-in. well 1,646 ft. deep, extending 241 ft. into the St. Peter limestone. The supply is pumped, and since 1900 it has been increased by the air-lift system. In 1901, a brick and concrete storage reservoir of 1,137,000 gallons capacity was built. The cost of pumping is 6¼ cts. per 1,000 gallons, and the water is paid for by the meter system, 420 meters being in use. Besides the reservoir there is a receiving basin at the artesian well, and a tank 40 × 12 ft. on a brick tower 60 ft. high. This holds 28,000 gallons and gives 44 lbs. pressure. The city has 12 miles of 4 to 12-in. mains, and 113 hydrants.

A paper on "The State Dam and Tail Race at Joliet" was then read by Mr. J. W. Alvord (Chicago), dealing largely with the litigation between the Sanitary District of Chicago and the Illinois & Michigan State Canal. The works as designed by Alvord & Shields, after the conclusion of the case, include a tail race 75 ft. wide, 1,000 ft. long, and 15 to 35 ft. deep, cut out of the solid rock. The old dam was cut away and a new concrete dam built, with a by-pass tunnel.

After the reading of a paper by Mr. W. M. Hay on "Practical Resurveying," which referred to city work and brought out some discussion on street lines and monuments, the session adjourned.

At the evening session, the report of the Committee on Roads and Pavements was read by the Secretary. It discussed particularly the liability of stone roads in clay districts being spoiled by being "picked up" by the sticky mud on the wagon wheels. This has caused considerable injury to chert roads at Bloomington, but these roads were not well rolled and not sprinkled during construction. Chert roads at Cairo give good results, but are in a sandy district.

The City Engineer of Joliet, Mr. H. A. Stevens, then read an interesting paper on "Street Paving Practice in Joliet." Asphalt is now the favorite material, but is not laid against the street railway rails. Paving bricks are laid against these rails, there being two stretchers (side by side) between each pair of headers so as to make a strip of nearly uniform width. A paper on "Wagon Roads and Civilization," written by Prof. I. O. Baker (University of Illinois) in his usual interesting style, was then read by the Secretary. Professor Baker pointed out that the condition of the roads was no indication of the degree of civilization in any particular community. Comparisons between the roads of Europe and America cannot be properly made, owing to the different conditions of population, internal commerce, etc. France, with its good roads, has a density of population four times as great as that of Illinois, and pays 50 cts. a day for labor, as compared with $1.50 in Illinois. France also spends on its roads four times as much per mile and twice as much per capita as is spent by Illinois. Many of the earth roads of Illinois are good for eight or ten months of the year. Professor Baker referred to the injury which road reformers have done to the good roads movement by trying to persuade farmers that they can save large sums of money by building stone roads. Arguments of a similar character, and of equal force, could be brought forward in favor of building roofs over sidewalks, to save the wear and tear of umbrellas, the injury to health by people getting wet, and the loss of time to business men in waiting under shelter till the rain has stopped.

A paper on "Concrete and Melan Arches" was then read by Mr. L. K. Sherman, Bridge Engineer of the Chicago & Western Indiana R. R., and some extracts from this are given below.

CONCRETE AND MELAN ARCHES.

The methods in common practice for the design and computation of stresses in voussoir arches are recognized as unsatisfactory, and are still more unsatisfactory when applied to concrete and Melan arches. The main trouble arises from the attempt to compute the stresses by means of the principles of statics, when the arch (with the exception of the three-hinged arch) is a statically indeterminate structure. The joint of rupture is considered as hinged, whereas in concrete and Melan arches it is not so, but has a bending moment that replaces considerable of the otherwise necessary crown thrust. The elastic theory of Weyrauch for the computation of arches is based on the well-known law that the stress is proportional to the strain for homogeneous materials within the working limits of stress. The most valuable investigations made on arches are those of the Austrian Society of Engineers and Architects (Eng. News, Nov. 21, 1895; April 9, 1896), and the very important conclusions derived from the tests were (1) that masonry arches behaved very nearly as elastic arches fixed at the ends, and (2) that all large arches should be designed according to the elastic theory. A drawback to the use of this method has been the somewhat formidable array of mathematical formulas, but it is not necessary to use the calculus in solving these formulas. A series of diagrams should be made, covering any type or shape of arch, and with such an arrangement the stresses could be computed as quickly and accurately as those in a truss bridge of the same span.

A fixed arch is more rigid and free from vibration than a hinged arch, and should be used wherever a solid foundation exists, but if there is any danger of movement of the abuments the three-hinged arch should be used. Among European engineers it is general practice to leave joints or temporary hinges in the arch during construction, these being closed after the centers have been removed. Temperature stresses do not demand hinges in any type of arch. Temperature changes may cause a crack in the spandrel wall over the springing, and it is well to provide this wall with a joint. The success with the combinations of concrete and steel is due to the fact that there is not a great difference between the coefficients of expansion of the two materials, and also the fact that there is a remarkably strong adhesion of cement to iron, from 400 to 600 lbs. per sq. in.

The concrete for arches should have 1 part Portland cement to 7 parts of aggregate, should be thoroughly mixed, and then tamped in layers of 6 or 8 ins. The writer prefers a fairly wet or quaking mixture, the arch ring, however, being a little drier, which necessitates extra tamping. The arch ring should be constructed in one section if possible, or else the work should be finished in radial lines. The facing mortar should be placed at the same time as the concrete and bonded with it; a mortar of 1 to 3 is as durable as that of 1 to 2, and is less liable to crack during setting.

The principal advantage of the arch over a truss or girder bridge is in beauty and durability. A concrete arch is cheaper than a stone arch nearly in proportion as concrete is cheaper than cut-stone masonry. A concrete arch reinforced with embedded steel beams can be so designed that it will be cheaper than the plain concrete structure, while it has a larger factor of safety. There are many cases, where foundations are favorable, in which the first cost of the arch will be less than that of a truss.

In a short discussion on "Protecting Earth Embankment Slopes," Mr. A. L. Kuehn (Urbana) referred to the use of brush for preventing sand from drifting and sod to prevent earth from washing. Mr. E. E. R. Tratman (Associate Editor of Engineering News) referred to the fact that some railway embankments in Iowa are now being built 45 to 50 ft. wide on top, simply to allow for the washing of the slopes before the bank becomes consolidated. The subject of "Preventing the Rusting of Nails and Spikes" was then taken up, and Mr. Kuehn spoke of the use of galvanized nails in places along the Gulf coast.

At the meeting on Jan. 23, the report of the Executive Board was presented, which recommended that a printed synopsis of the papers should be sent out before the next meeting. The report of the Secretary showed a membership of 114 and a cash balance of $63.

A final report of the Committee on Paving Brick Specifications and Tests was presented by Prof. A. N. Talbot (University of Illinois), and the committee was discharged. Mr. S. S. Greeley (Chicago) then read the report of the Committee on Surveyors' License Legislation. A bill requiring the licensing of surveyors was introduced in the Senate and House at the last session of the state legislature, but was defeated in the former and consequently dropped in the latter. Mr. W. P. Feeney read a paper in which he explained that one objection made to the bill was the fact that it would not prevent a surveyor from sending out incompetent men to do the work, while he would sign the plan as being correct. Several cases of this character were cited, and a sharp discussion as to whether this could or should be provided against by legislation occupied the remainder of the morning session; some members considered that a bill should be prepared requiring a chief of party to be a licensed surveyor, while others thought the society should drop the whole matter. The latter course was subsequently decided upon.

In the afternoon the party visited the controlling works of the Chicago Drainage Canal at Lockport, the great bear-trap dam being operated for their benefit. On returning they visited the water power and electric generating plant of the Economy Light & Power Co., at Joliet. In the evening, Mr. M. S. Ketchum (of Champaign) read a paper on "Steel Frame Mill Buildings," describing the general character of the design and the methods of calculation employed in computing stresses, determining weights of roof trusses, etc. A paper on "The Purification of Sewage," by Mr. W. S. Shields, was then read, one of the particular points of which was to show that the septic tank is not in itself a complete or final system of purification, but must be supplemented by some treatment of the effluent, either by broad irrigation or sand filtration. The recently built plants at Wauwatosa, Wis., and Lake Forest, Ill., were described.

On motion of Mr. E. E. R. Tratman, the following resolutions were adopted:

Resolved, That in the opinion of this society it is desirable that the United States Census should include municipal statistics in its inquiries, particularly those relating to the nature and extent of municipal public works.

Resolved, That this society is heartily in favor of a permanent census or other statistical bureau at Washington, which shall include in its staff experts in municipal engineering, finance and allied subjects.

Resolved, That a copy of these resolutions be sent to the Hon. William R. Merriam, Director of the Census, at Washington, and to our representative in Congress.

The party then adjourned to pay a night visit to the Joliet works of the Illinois Steel Co., passing through the blast furnace and Bessemer converter departments, with the reheating furnaces, and then proceeding to the rolling mill, wire mill and spike mill.

At the morning meeting on Jan. 24, the first paper presented was one by Mr. W. A. Rogers, of Chicago, on "Concrete Structures for Railways," and a brief abstract of this paper is given below:

CONCRETE STRUCTURES FOR RAILWAYS.

During the past few years the use of concrete in the construction of various structures for railways has increased materially. Piers and abutments for bridges, pedestals for steel trestles, and culverts (either arched or with flat roof of rails or I-beams and concrete), retaining walls, etc., are among the more common uses. Concrete is also used for cinder pits, turntable pits, pumping posts, floors, foundations, and even the complete superstructure of stations and shop buildings. It is largely used where stone masonry has formerly been used, and is an ideal material for arch construction, more particularly skew arches. Concrete arches of 5 ft. to 100 ft. span are being built, the larger ones being ordinarily reinforced by steel in some form.

While natural cement has been successfully used for work above ground, there are enough instances of such concrete being damaged by frost as to make it wiser to use Portland cement, especially as the difference in cost of the two kinds of concrete is so slight. The proportions for railway work are 1 to 1½ to 4 or 1 to 2 to 5 for natural cement concrete, and 1 to 2 to 4 or 1 to 4 to 9½ for Portland cement concrete. The use of sand or gravel which is not strictly clean, and even sand containing loam or clay, is warranted both by laboratory tests and by actual experience. Hard stone screenings used instead of sand have given good results. The use of gravel instead of sand is becoming quite customary, the relative proportion of sand and stone in the gravel being determined, and enough broken stone added to make the required proportion in the mixture. Cinders, slag, and even burnt gumbo or clay, are used in some cases.

In railway work, the tendency is to use a wet mixture and to form the surface without a special mortar facing. Stone bearings or bridge seats on concrete abutments are being abandoned, the seats being formed of the ordinary concrete or a specially strong mixture. Careful mixing should be the rule, and it is false economy to attempt to effect a saving by slighting this labor. The foreman on the work should certainly be experienced in concrete construction. In bridge work, concrete can be built with less interference to traffic than is practicable with stone masonry, and in very much less time than a steel bridge, when the delay at the mills is taken into account.

The report of the Committee on Surveying was then presented by Professor Talbot, and the question of legislation for licensing surveyors again came up, but was disposed of by the passage of a resolution to the effect that the society should drop the matter.

The report of the Committee on Railways was then read by Mr. E. E. R. Tratman; it dealt more particularly with the steam and electric railway work done in the state during the past year, and also with the development of the College of Engineering at the University of Illinois. This report led to some discussion on electric railways, in which Mr. Kuehn referred to the necessity of good terminals and to the fact that an electric railway may often cost as much as a steam road, although in the country districts there is an impression that electric railways can be built at a merely nominal cost. The report called special attention to the fact that there is now a period of inflation and speculation in electric railway development, and that many railways already built and apparently prospering are making no provision for possible hard times or for fixed charges, and the inevitable deterioration of plant. The following is an extract from this report:

The building of electric railways to open up new territory, to develop new traffic and to parallel existing steam railways goes merrily on, but your committee is inclined to think that there is danger of carrying this to an extreme, with the result that the present "boom" will be followed by a collapse similar to the periodical depressions which have followed the over-building of steam railways. As long as times are flourishing, money is plentiful and plants are new, the railways spread and prosper. But with fixed charges to meet, and deterioration of plant to be provided for in a time of general depression, it seems likely that many of the projects now before the public will have difficulty in weathering the storm. This is more particularly true of such lines as are of a purely speculative character, often paralleling steam roads or even other electric roads.

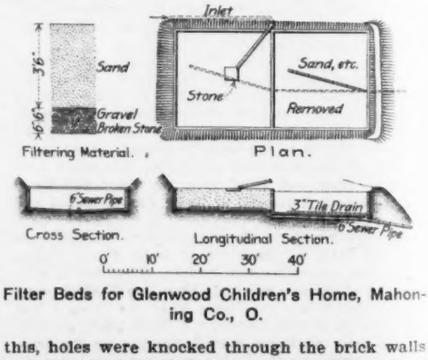
Mr. H. A. Stevens presented the report of the Committee on Exhibits, which commended the large exhibit of surveying and drawing instruments made by Keuffel & Esser, of Chicago, and suggested that at the next meeting an endeavor should be made to have exhibits of materials and manufactures (such as cement, clay, paving brick, sewer pipe, etc.,) from different sections of the state. A paper on "Records of the Maintenance-of-Way Department of the Rio Grande, Sierra Madre & Pacific Ry. (Mexico)," by Mr. L. P. Atwood, Engineer of Maintenance-of-Way of that road, was then read, and described methods very similar to those of the smaller railways of the United States. The last paper was by Mr. C. C. Stowell, of Rockford, on "The Location and Construction of an Electric Interurban Railway," which brought out some further discussion on the line of that following the report of the Committee on Railways. Some notes of this paper will be given later. After passing the customary resolutions of thanks, followed by brief addresses by the new officers, the society adjourned.

The officers for the ensuing year are as follows: President (re-elected), H. G. Paddock, City Engineer, Moline; Vice-President, E. E. R. Tratman, Associate Editor of Engineering News, Chicago; Trustees, H. A. Stevens, City Engineer, Joliet, and M. S. Ketchum, University of Illinois, Champaign; Secretary and Treasurer, A. L. Kuehn, University of Illinois, Urbana. The next meeting will be held at Aurora, Ill., in January, 1903.

SEWAGE DISPOSAL FOR THE GLENWOOD CHILDREN'S HOME, MAHONING COUNTY, OHIO.

An excellent example of the evil results of the failure to employ an engineer for engineering work is shown by the recent experience of Mahoning County, O. In 1900, the trustees established a children's home in the extreme southwestern corner of the city of Youngstown. The place is known as the "Glenwood Children's Home," and in December, 1901, housed some 20 children and five attendants. The institution is supplied with water from the Youngstown waterworks, but it is so located that it is impossible to obtain an outlet to the city sewers, making it necessary to provide an independent system.

The trustees intended to put in a septic tank with coke filters, patterning the system after the neighboring Trumbull County Infirmary works, which are in successful operation. A local architect, however, convinced them that the expenditure of several thousand dollars was not necessary, and that he could solve the problem with much less money. Accordingly, a brick cistern, 10 × 14 ft., × 10 ft. deep, was constructed, all underground, and divided into three compartments by two dry brick walls. The first compartment, it seems, was filled with coke, the second with broken stone, and the third left vacant to serve as a manhole. The sewage in passing this contrivance was compelled to percolate through the coke, a brick wall, the broken stone, and finally another brick wall. As was to be expected, the sewage very quickly rendered the brick walls impervious and failed to pass through, filling the cistern and flowing out of the manholes. To avoid



Filter Beds for Glenwood Children's Home, Mahoning Co., O.

this, holes were knocked through the brick walls and the sewage allowed to escape. For a short time it filtered through the coke and stone, but finally clogged these up and flowed over the surface of the beds to the outlet.

Such a local nuisance was caused thereby that in the summer of 1901 steps were taken to put in an efficient system. Acting under the advice of Mr. E. G. Bradbury, it was decided to clean out the old cistern and cut off a portion of same for use as a collecting and flushing basin, and to put in two intermittent sand filters, each 400 sq. ft. in area. Owing to the extreme slope of the ground, it was very easy to find a suitable location where the sewage would pass onto the filters by gravity from the collecting basin. This basin was arranged by placing a brick wall, 3 ft. high, across one end of the cistern and at such a dis-

tance from the end that the cut-off portion would hold about 1,000 gallons. The sewage is to be discharged from the bottom of the tank through an opening in the brick wall, controlled by a gate, operated by hand. The daily flow of sewage approximates 1,000 gallons, and it is the intention to open the valve once each day discharging the sewage onto the filters alternately every other day.

The filters, as shown in the illustration, are contained in two basins, each 20 ft. sq. and 4½ ft. deep, constructed with 6-in. concrete walls backed with clay and 3-in. concrete bottoms. Each bed has one 3-in. soft tile underdrain, connecting with a short 6-in. outfall drain, leading to a dry run which is tributary to Mill Creek at a point about 1½ miles above the confluence of the latter with the Mahoning River. The filters contain from 3 to 6 ins. of broken sandstone, 6 ins. of gravel, and 3½ ft. of a rather fine bank sand, with an effective size of 0.24-millimeter and a uniformity coefficient of 1.84. The sewage is brought to the center of one side of the filters by a 6-in. sewer, and it is distributed to the desired bed by a movable sheet-iron pipe. To prevent washing the beds, a stone slab, 3 ft. square, will receive the discharge from the pipe.

The old cistern, with its coke beds, cost $360, and it is estimated that the new filters, with the changes in the cistern, will cost about $500. The filter basins have been completed and the filtering material was, on Dec. 9, being put in place, and it was expected to have the plant in operation very soon.

FLEXIBILITY IN CAR COUPLING ATTACHMENTS.

In discussions on the improvement of car couplers and their attachments it is not infrequently claimed that greater flexibility is desired than is provided by the present couplers, and this particular phase of the coupler question has recently been brought up for discussion before the Western Railway Club and the St. Louis Railway Club. This flexibility is partly to facilitate coupling cars together on curves, and partly to relieve the pressure against the rails by the wheel flanges of trains passing around curves. The necessity for such increased flexibility is by no means universally accepted, but manufacturers and railway officers have devised special couplers and coupling attachments to meet the assumed requirements. These devices may be divided into two systems: (1) A coupler head independent of and pivoted to the drawbar; (2) a drawbar held by some form of pivoting attachment at its rear end, and allowed increased lateral play in the carry-irons. The general question of improvements in couplers we have discussed in another column.

A paper on "The M. C. B. Coupler," by Mr. R. P. C. Sanderson (Purchasing Agent of the Seaboard Air Line), was presented at the October meeting of the Western Railway Club, and in this paper particular attention was given to the matter of flexibility in the couplings. From this paper we take the following extracts:

When M. C. B. couplers are made with a reasonable degree of correctness as to contour lines and twist, so that they will pass the gages, the lines will permit of angling between the two heads to 14° on either side of the center line, which is more than ample for everything but sharp warehouse curves or leads in coal yards. When cars of approximately equal length are passing around a curve, the couplers are under no lateral strain, but simply angle upon one another. But this condition, and when running over straight tracks or very slight curves are the only conditions when the couplers are not under some lateral strain. There is necessity for the lateral movement of the couplers; (1) when the cars are passing from a tangent to a curve, or the reverse; (2) when cars are passing around a reverse curve; and (3), when cars of different lengths are passing around the same curve.

One of the absolute necessities of the M. C. B. coupler, if it is to couple without men going between the cars to line up the heads, is that the couplers shall line up pretty closely, otherwise the lugs or knuckle face will strike on the end of the guard arms, resulting in mixed couplings and damaged couplers. Therefore, only a very little clearance can be safely allowed between the sides of the coupler shanks and the carry-iron bolts or chafing pieces as now arranged.

While it is impossible to estimate what the lateral pressures really are, yet a very real conception of the importance of this matter can be obtained by making tests similar to those made by Mr. Schroyer (noted below.—Ed.), with freight cars of varying lengths, such as short coal cars coupled to long furniture cars moving on single and reverse curves up to 14° or even 20°. Neither can anyone, even after such tests, estimate what the saving in car and track repairs would be if all lateral pressure were eliminated, but we know there will be a saving and it is surely worth striving for. Already many roads have recognized this trouble for their passenger equipment and use a long shank coupler, having the draft attachments well back near the bolsters, and a wide carry-iron provided with lateral springs to bring the couplers back to a central position after uncoupling.

According to correct mechanical principles, the draft attachments should be as close as possible to the truck center, thus relieving the car frame from lateral bending. This, however, requires a long coupler shank which is weak in buffing shocks and would bend; besides, such an arrangement would greatly increase the cost of the cars. Considering the vast number of modern cars now in service, and the cost of making any radical change, it is believed that the following suggestions will cover the points and bring the results at insignificant cost, and this arrangement can be readily applied to the present cars, if thought desirable.

1. Allow 2½ or 3 ins. for lateral movement of the coupler head on either side of the center line.
2. Apply lateral springs to the carry irons to return the coupler to its central position when unoccupied.
3. Make the back face of the back follower lightly convex, so that the coupler and yoke can swing from that point as a center without the strain coming on the edges of the yoke iron.
4. Guide the back of the yoke so that it cannot get out of its central position.
5. Make the front face of the front follower convex to a raidus equal to the inside length of the coupler yoke.
6. Make the lateral springs long and amply strong enough to readily return the coupler to its central position, but avoid unnecessary stiffness. In this way the present coupler and yoke springs and draft gears can be retained, only the followers with the carry-iron and its lateral springs, with the malleable iron pockets and chafing stirrup, need be of new design.

It has been contended that the swing motion truck is the true remedy for the difficulties referred to in this paper; but the swing motion truck has troubles of its own, and it is not believed to be good mechanical design to try to overcome defective design in the draft gear by modifying the trucks. Rather the trouble should be properly provided for in the draft gear itself.

The arrangement suggested by Mr. Sanderson is shown in Fig. 1, its special features being the convex form of the follower (on which the coupler moves with a radial motion), and the use of centering springs. A similar arrangement, as far as the springs are concerned, has been used in 60-ft. cars of the Cleveland, Lorain & Wheeling Ry., which were illustrated in our issue of May 9, 1901. In discussing the paper, Mr. F. H. Stark, Master Car Builder of this railway, stated that in these cars a lateral play of 1½ ins. on each side of the center is allowed, and that the centering springs perform their functions very well. He approved of placing the draft attachments well back under the end of the car, but considered that difference in the lengths of cars coupled together did not cause so much trouble as does the overhang from the bolster to the coupler.

Mr. C. A. Schroyer, Master Car Builder of the Chicago & Northwestern Ry., gave an interesting discussion, in which he referred particularly to the conditions existing where a car is coupled to a tender, the latter having only a coupler head, without a drawbar. He also stated that at the time the M. C. B. coupler was adopted, the swing-motion truck was in general use, but after its adoption there followed a tendency to adopt the rigid-beam truck, and very few roads are now using the former. An abstract of the remarks made by Mr. Schroyer, and Mr. Robert Quayle, Superintendent of Motive Power of the same road, is given below:

Mr. Schroyer: Some five or six years ago we endeavored to ascertain the extent to which the difficulty was occasioned in the use of M. C. B. couplers between our tenders and passenger cars. We fitted up one of our officers' cars, 60 ft. in length, and a tender, and ran them around a 15° curve. We first ran them around by the heads of the bars coming together, but not in coupling contact, and found that the lateral movement was 12 ins.; that had to be absorbed somewhere. We make provision in our passenger car trucks for a lateral movement of the body bolster, 2 ins. either way from the center, thus giving 4 ins. in all. We had in the yoke that carried the coupler 1½ ins. lateral movement in each side, and no lateral movement was had on the tender except what there would be on the journals and what little there might be on the springs. We coupled the car and tender together and then ran them around the curve. Of course, the stem of the coupler, the carrier iron and the truck bolsters were crowded over to the side, but the car went around the curve all right.

It then occurred to us to measure the pressure. So we cast some lead blocks, and filled up the entire space between the stem of the coupler and the side of the carrier iron or yoke, and then ran the car around the curve. We found that the compression was about 3-16-in. We took the mate to that block and put it under our testing machine, and it required about 57,000 lbs. to press that block into the same shape as the first one. Now the car went around the tracks successfully with that block and yet we know that those strains were absorbed somewhere.

Cars to-day are being handled successfully with the automatic coupler and no provision made anywhere for any lateral movements. There is no place on the C. & N. W. Ry., that I know of, where any special devices are used for getting those cars around curves. We are running 50-ft. cars coupled to 32-ft. cars. We have made it a point in the construction of our cars to keep the trucks as near the ends of the cars as we can, to avoid those lateral movements as much as possible. So while I consider the claims made by Mr. Sanderson, in so far as these lateral movements are concerned are all right theoretically; practically these cars are running around without any perceptible damage anywhere, although no one pretends to deny but that they do have their effects eventually in the construction of the car. While I question very much whether it would be best to absorb these lateral movements by means of a swing motion truck, or by means of the lateral plays in the yoke or carrier iron, it certainly should be done somewhere.

I do not believe the lateral play of the coupler is necessary to-day, except in extremely long cars or extremely short cars; in cars of nearly uniform length, no provision need be made for it. A very large percentage of the cars in operation to-day are of uniform length, and these points do not apply. We have some 50-ft. cars that are running right along, but the trucks are as near the ends as we dare put them, and they are running first-rate, as far as we know. On the tenders which have a very short overhang, and also on cars that have a short overhang (there are, I believe, passenger cars that have a 12-ft. overhang) there is provision made to compensate for that lateral motion.

Mr. Quayle: I assisted Mr. Schroyer in making the tests referred to. When we passed around the 15° curve, I was surprised to see that the flanges on the wheels had almost crawled up onto the rails, and I think if a little more pressure had been given, it would have gone over onto the ties, and we were only moving about three miles an hour at the time. It seemed to me at that time that it was necessary to give attention to the effect on curves, and in all the equipment we have rebuilt or purchased since that time (now nearly six years ago) we have been putting in almost identically the scheme that Mr. Sanderson has outlined here, except that we do not use the convex follower plate but instead use filler blocks on each side of the follower plate that are convex. This, of course, refers only to our locomotive tenders.

We have had no difficulty whatever in breakages in this form of construction in our tenders. I might also add that we have a total of 5 ins. lateral motion, or about 2½ ins. on each side of the center and we consider it to be a very good thing, particularly when a buffet car with about a 12-ft. overhang is coupled to the tender.

So far as relates to freight cars, I think it is rather a big undertaking to commence now to make all these changes and perhaps it is not necessary where the cars are so nearly of uniform length. This proposition, however, could be considered in connection with new equipment, were it deemed necessary. I think sometimes it is a good thing not to have too much lateral motion going around curves, because they right themselves better than they would do by the excessive jerking motion they would get by too much lost motion, and this would be particularly true if swing-motion trucks were used.

In regard to these lateral strains on the couplers; they are absorbed by the wheels, by the bolsters, by the couplers, and by the carrier irons. Our records of broken couplers show that there is a very small percentage of couplers broken off at the head, or where the head is broken off in the stem. That is where the strain comes, and the percentage is very small as compared to the percentage of guard arms that are broken.

A part of the discussion naturally turned upon the use of couplers having the head pivoted to the shank or drawbar. Mr. Charles Lindstrom, of the Chicago & Alton Ry., considered that the proper remedy for the difficulties under discussion was to produce a coupler construction which will permit the excessive side motion without reducing the angle within which the couplers adjust themselves, since this angle cannot be reduced without breaking the knuckles. Therefore, while it is proper to increase the side play, especially on tenders, this should be done by having the head pivoted to the shank. A proper construction of a coupler for tenders would have a parallel motion (allowing the coupler to be shifted over sideways without any change in the angle), or a two-fold motion (side play of the shank and swiveling of the head).

This is a feature to which coupler manufac-

turers have given some attention. The Washburn Coupler Co., of Minneapolis, sent in a written discussion relative to its "flexible head" couplers, from which we take the following extracts:

Three years ago we commenced experimenting with a coupler with a flexible head. These couplers have been put in use, and at this time over 1,500 are being used in the United States and Canada. While this device seems expensive upon freight equipment, we believe that in the long run it will prove economical. There is at no time any strain upon the frame of the car. This has been proved in service, and one car which has been running for over 2½ years with a pair of flexible head couplers has never had any repairs made upon the platforms, nor any tightening of the bolts.

The flexible-head coupler does not wear out as fast as the rigid-head type. We know of one knuckle which was in use over two years before it was removed, and there is another knuckle, absolutely identified, which has been running now over 2½ years. This in passenger service, which is always the most severe upon knuckles. We also find that the wear of the knuckle against the face of the coupler is not so great as in the rigid-head type. There is never any grinding sideways or up and down with this type of coupler.

The flexible-head couplers pull over the center line of track. This insures the wheels following the track absolutely. For some time we painted the flanges on a passenger car equipped with our flexible-head couplers, which car made long runs, and we found that there was a decided difference between the wear on the flanges of this car and another car in the same train which had rigid-head couplers.

We obtain from the flexible head over 2½ ins. side play. We also furnished carrier irons with springs and thimbles which give at least 2½ ins. side play. We have others which give much more. Lateral springs in our carrier iron return the coupler to a central psoition when uncoupled. The flexible-head couplers will couple even if they are not absolutely central. The first shock of contact being sufficient to-bring them into a central position, and they will then couple.

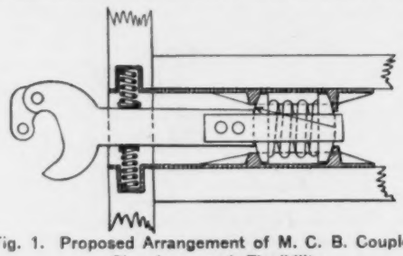


Fig. 1. Proposed Arrangement of M. C. B. Coupler to Give Increased Flexibility.
R. P. C. Sanderson, General Purchasing Agent; Seaboard Air Line.

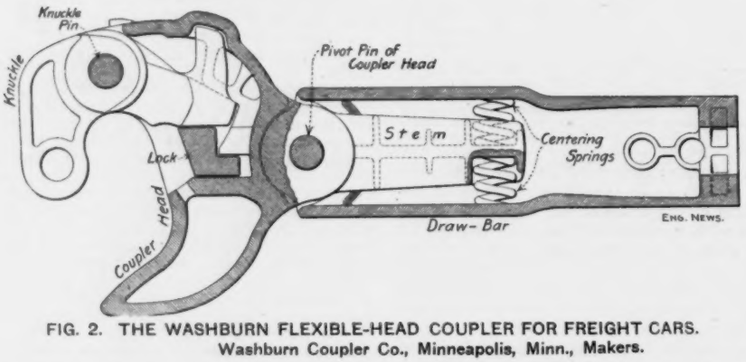


FIG. 2. THE WASHBURN FLEXIBLE-HEAD COUPLER FOR FREIGHT CARS.
Washburn Coupler Co., Minneapolis, Minn., Makers.

The Washburn flexible-head coupler as designed for passenger cars has a head of the usual M. C. B. form pivoted by a vertical pin in the end of the hollow drawbar. A stem or tail projects within the drawbar, and has lateral pieces set up by centering springs on either side, so that the head is normally held in line with the drawbar and is automatically returned to that position after having been diverted from it by the lateral strain exerted upon the coupling by the cars passing around sharp curves. The freight car coupler, shown in Fig. 2, has a shorter drawbar with springs set inside, bearing directly against the stem of the coupling head. In the pilot and tender couplers, a hollow casting bolted to the bumper beam or sill takes the place of the drawbar. The following letter, written to us by this company in reply to a request for information, is of interest, but indicates that the coupler is used more for the special conditions incident to engine and tender couplings than for the ordinary coupling of freight cars:

There are now about 800 of our flexible-head couplers of various types in use. We have supplied a considerable number of these to F. M. Hicks, of Chicago, who has placed them on locomotives and sold these locomotives to various roads whose names we do not know, but we know of 20 roads upon which this coupler is in use. It is standard for pilots on the Soo Line, and the Canadian Pacific Ry.; and the passenger coupler is standard upon the Soo Line and the Great Northern Ry. The Canadian Pacific Ry. has also a number of the passenger couplers in use. We have sold a number of these flexible-head couplers to various locomotive works in the United States and Canada, and the flexible head freight coupler has been placed upon cabooses on the Great Northern Ry., and the Bismarck, Washburn & Great Falls Ry. At the present a number of railways are experimenting with this coupler.

The McConway & Torley Co., of Pittsburg, Pa., also submitted a discussion on this subject, dealing entirely with the company's Buhoup three-stem coupler, which has three stems in place of a single drawbar, with the coupler head pivoted to the drawbar and having side lugs to which the stems are connected. This was claimed to be much easier than the ordinary coupler in passing sharp curves, even without extra lateral play, which, however, can be given if desired. In 1898, two gondola cars 35½ ft. long over the sills, with trucks 24 ft. c. to c., were fitted with these couplers, and no trouble was experienced in passing from an 80-ft. curve to a tangent, or in passing reverse curves of 400 ft. radius. On a 66-ft. curve, the corners of the end sills were in contact, but there was still lateral movement left in the coupler and rotative movement left in the heads of the couplers. It was subsequently found that the axes of the two couplers made an angle of 34° 30′ before the lateral and rotative movement was all absorbed.

Fig. 3 shows the construction of this coupler as designed for 50-ton steel freight cars and the device can be readily applied to existing freight cars. The center stem is fitted to any ordinary style of draft attachment and springs, and the springs on the side stems are given an initial compression of 1½ ins. Buffing blows on the guard arm are less serious than in the ordinary coupler, since the blow is cushioned by the side spring and by the coupler head turning on its center, so as to yield to the blow. In case of breakage, the coupler can be readily removed, and any ordinary single-stem coupler put in its place. Up to the present time this coupler has been applied mainly to passenger cars, in connection with platform buffers and vestibules, but in view of the general introduction of heavy, high-capacity freight cars, the makers now intend to give more particular attention to freight equipment. The cost is, of course, considerably higher than the plain single-stem coupler, but the increase of cost in the coupling arrangements is claimed to be well warranted by the increased weight and cost of the cars themselves, and by the greater safety ensured by the greater strength in the couplings and the reduction of strains upon the axles and wheels in passing around curves. Concerning this coupler, the company writes us as follows:

This Buhoup three-stem equipment is already in service on upward of 2,500 passenger cars, to which class of

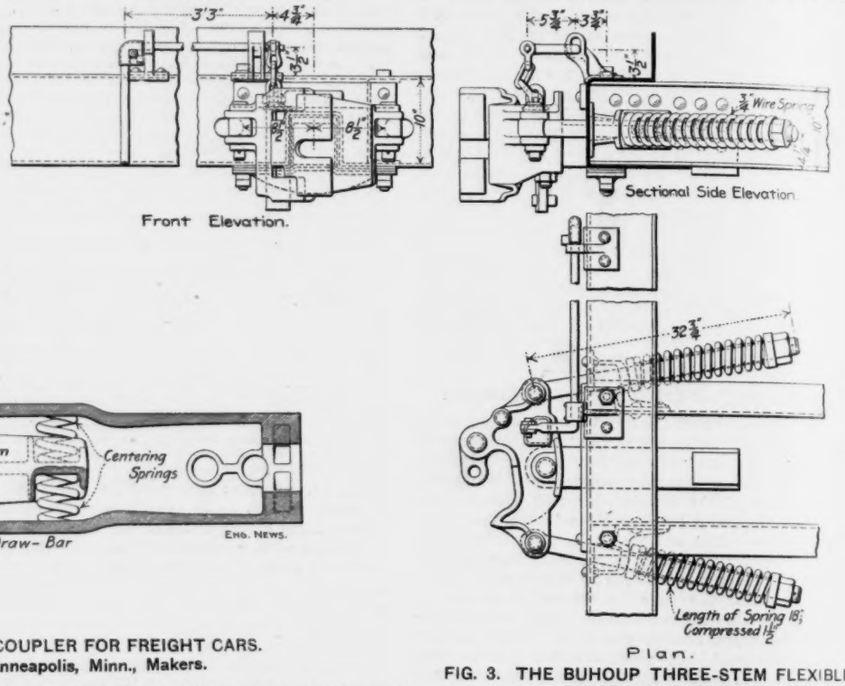


FIG. 3. THE BUHOUP THREE-STEM FLEXIBLE-HEAD COUPLER.
McConway & Torley, Pittsburg, Pa., Makers.

equipment we have been applying it for the past six years. It was applied to three freight cars in May, 1899, and has also been applied to some considerable extent to tenders of locomotives, but the exact number of equipments in such service we have not recorded.

There are, of course, other makes of couplers with swiveling heads, and in a paper read before the St. Louis Railway Club in September, Mr. J. B. Taylor, Secretary of the American Railway Supply Co., described a coupler of this kind which he has designed, but which has not yet been put in use. Mr. Sanderson, however, does not consider that this style of coupler meets the difficulties which he has outlined, and we conclude our presentation of the subject by quoting his remarks upon this point in closing the discussion of his paper:

With regard to the swiveling-head coupler, brought forward as a remedy for the troubles referred to, it is not certain whether this is the best method of meeting the difficulty, although it will no doubt mitigate the evil effects. The M. C. B. contour lines, if correctly followed, allow of angling on either side of the center line so that a car will pass around a 30° curve without the couplers binding injuriously; consequently it ought not to be necessary to put in hinged heads to provide for what is already covered in the contour lines. It is lateral freedom that is needed, and it is doubtful if provided a swiveling-head is the correct way of providing for this. It seems also as if the swiveling-head would be objectionable and cause trouble when trains are being pushed or when the slack runs up in heavy trains, by a tendency to double up at the hinge.

The writer is pleased to see that at last some of the members, who discuss the paper, appreciate the importance of the main point which it was attempted to bring out, namely: that with the coupler as it is at present constructed it is most necessary that lateral motion (controlled by springs) should be provided at the carry irons if the wear of the wheels, rail heads, damage to couplers and car framing is to be reduced.